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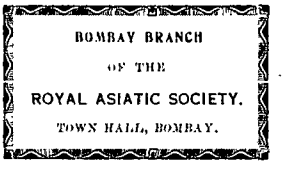

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INDEX CHART
TO THE
AT TRIGONOMETRICAL SURVEY
OF
INDIA

GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1871-72,

Prepared for submission to the Government of India.

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BY

MAJOR T. G. MONTGOMERIE, R.E., F.R.S., &C.,

OFFG. SUPERINTENDENT G. T. SURVEY.

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Dehra Dun:

PRINTED AT THE OFFICE OF THE SUPERINTENDENT G. T. SURVEY.

M. J. O'CONNOR.

1872.

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THE OPERATIONS OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA

IN 1871-72.

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(1.) The operations of the Great Trigonometrical Survey during 1871-72 have been much the same as during the previous year, and have produced the following out-turn; viz., of Principal Triangles with great theodolites 64 triangles, covering an area of 10,310 square miles with a total direct length of 396 miles, and observations for 3 azimuths of verification; of secondary triangulation with smaller theodolites an area of 13,530 square miles on which the positions of a large number of points were fixed and the heights of 783 were determined; of Topographical Surveying on the scale of two inches to the mile 3,418 square miles, on the one inch to the mile scale 1,279 square miles; of boundary lines and check lines 1,608 miles; of main lines of double leveling 245 miles, by means of which the heights of 190 points of reference were finally determined; by Astronomical Latitude observations the Latitudes of 25 points were determined; of geographical explorations 844 miles of Route Survey have been reduced, by which the geography of an area of about 7,650 square miles of *terra incognita* has been unravelled.

Out-turn of Fnal Work.

(2.) The observations have been made with the usual care; and the precision reached in former years has been fully maintained as shown in the table given in the margin, the average probable error being only ± 0·21 of a second.

Observations.

Series.	Probable Errors of Observed Angles.		Errors of Triangles.	
	Number.	Amount.	Number.	Amount.
I ...	54	±0″·28	18	0″·62
III ...	57	·17	19	·59
IV ...	33	·14	11	·33
VI ...	33	·25	11	·39
Averages, ...		± 0·21	...	0·48

(3.) Besides the finished work enumerated above, there has been the usual out-turn of approximate work for the ensuing season's operations, including the selection and building of 35 new stations in extension over a total distance of 241 miles, clearing of hill tops of forest, cutting of rays &c., so as to prevent any delay in the steady advance of the operations at the opening of the next field season.

Out-turn of Approximate Work.

(4.) The amount of data supplied to the Topographical and Revenue branches of the Survey and to the other departments of Government has increased very much.

Data supplied.

(5.) Considerable progress has been made in preparing the materials for the 2nd Volume of the "Account of the Operations of the Great Trigonometrical Survey," and for the publication of the observations; and with the increased means placed last year at the disposal of the Computing Office, steady progress will be made in this important work, which once accomplished will place these very valuable records beyond all accidents and at the same time make them readily accessible for all general purposes.

Publication of Observations &c.

(6.) The increased means placed at the disposal of the Drawing Office has not only admitted of the publication of nearly all charts of the present year that have been received up to date, but has also enabled this office to publish by photo-zincography a considerable number of the Triangulation Charts of the earlier operations, of which up to this time nothing had been published, owing to there being no establishment for preparing them. There is now a prospect that the mass of these valuable compilations of condensed data will be forthcoming, in a form readily available, to all who may require to use them.

Triangulation Charts.

(7.) The preservation of the records has as usual been carefully attended to. Those in the Head Quarters Office of the G. T. Survey at Dehra are all in proper order, and the Officer in charge of the Surveyor General's Office *Calcutta, reports that the duplicates there are also in thorough preservation.

Records.

Charts of Levels.

(8.) Steady progress has been made with the reduction and preparation of the Level Charts for Upper India. A large addition has been made to the Tables of Heights with descriptions of the G. T. Survey Bench-marks, and the publication of them has been brought up to date. The demand for these tables continues to increase.

Leveling operations.

(9.) The main leveling operations have been continued on the original plan, and arrangements have been made to extend them through the *Bombay Presidency and ultimately through *Madras. An index chart showing the proposed sheets of Level Charts in *Bengal and Northern India, has been prepared and circulated to all Departments and Officers likely to require them. The co-operation of all concerned has been asked for; and Officers will, with the Index, be at once able to see whether they can in any way contribute materials for this work, to which the Government of India attaches so much importance. Materials for a number of new sheets have already been collected, and will be gradually made use of as the strength of the Drawing Office is developed; the means of doing this having been placed at my disposal.

Preservation of Stations.

(10.) The measures prescribed by the Government of India for the protection of the principal stations of observation have been carefully carried out. During the year 155 stations scattered over 33 districts have been repaired and taken over by the local authorities. Besides the above, almost all of those previously handed over have been reported on, and where necessary have been repaired, a duty which involves a great deal of labour; as, after the rains, many require petty repairs in order to prevent extensive damage. All the marks of the present year have been handed over to the local officials, with the exception of some in Madras which will be handed over before the end of this year.

(11.) An abstract of the operations of the various Survey Parties and Offices is given below. Further details will be found in the extracts from the Narrative Reports of the various Executive Officers, including my usual report on the Trans-Himalayan explorations, which have as before been carried out under my personal direction.

T. G. MONTGOMERIE, MAJOR, R.E.,
Offg. Supdt. Great Trigonometrical Survey of India.

NO. I.—TRIGONOMETRICAL.

THE BIDER LONGITUDINAL SERIES, ON PARALLEL 18°.

PERSONNEL,

W. C. Rossenrode, Esq., Depy. Supdt. 3rd Grade.
H. Beverley, Esq., Surveyor 1st Grade.
Mr. E. P. Wrixon, Asst. Surveyor 3rd Grade.

(12.) The operations of this Series were continued by Mr. Rossenrode who took charge of the party on the 6th November 1871 and marched into the field on the 20th December. The country traversed being very unhealthy, the party could not start earlier; pack-bullocks were the only means available for carriage; and, as the country was throughout both hilly and intricate, marching and arranging for supplies was a matter of very great difficulty, provisions having to be brought from great distances: but few villages occurring on the line of the series, great delay necessarily occurred in marching from station to station.

(13.) Whilst the atmosphere continued to be clear great progress was made; but the jungle fires commenced in the middle of February, as is usual in such countries, and from that time forward the progress was slow, depending as it did upon occasional showers to make the atmosphere sufficiently clear to enable the observer to see his signals on surrounding stations.

Wild animals were very numerous; the tigers were especially troublesome, as in that part of the country they infest the footpaths in order to seize unwary travellers.

(14.) Mr. Rossenrode overcame these difficulties with his usual energy, though he himself and the whole of the camp suffered from repeated attacks of fever. Fortunately Mr. Beverley was in camp when Mr. Rossenrode was first attacked with fever, and was able to relieve him from a portion of the work which would inevitably have came to a stand-still had Mr. Rossenrode been alone.

Towards the end of April Mr. Rossenrode had finished the Bider Longitudinal Series, closing on Káp and Dhár Hill Stations and effecting a junction with the Coast Series, thus completing a very difficult piece of work which, owing to the extreme unhealthiness of the tract of country traversed by the Series, had been more than usually trying to all engaged on it.

(15.) In addition to the above Mr. Rossenrode was able to observe at 4 stations of the Biláspur Meridional Series, the southern section of which will form the scene of the future operations of this party, starting from the stations Munas and Báli.

(16.) In spite of all the difficulties Mr. Rossenrode made very good progress, the principal triangulation covering an area of 3,041 square miles having made a direct advance of 128 miles. At the same time the approximate series was carried forward 115 miles more, by means of which arrangements have been made for effecting a junction with the northern section of the Biláspur Series.

(17.) The secondary triangulation covers an area of 2,109 square miles in addition to the principal work; more secondary work and greater detail in that triangulated would have been effected had it not been for the sickness which crippled every one in camp.

(18.) Fortunately during the ensuing season the work will be in the Bastar and Jaipur states where it is believed the country will improve as the party advances to the north; the country generally rising to a considerable altitude above the sea, it is hoped that the party will suffer less from sickness.

No. II.—TRIGONOMETRICAL.

THE ASSAM VALLEY TRIANGULATION.

(19.) This triangulation, under Mr. W. G. Beverley, was continued to the East up the Assám valley. Owing to the Lushai expedition being in progress, the civil authorities had come to the conclusion that the wild tribes on the low hills adjoining the valley would be hostile, and the district officers had consequently been directed to erect stockades to prevent the tribes from entering the Assám valley. This being the state of affairs it was quite impossible that the triangulation could be carried over even the outermost portion of the hills, without a very much stronger guard than the civil authorities could supply at such a time. The officer in charge was consequently reluctantly compelled to alter all his arrangements in order to carry the Series through the plains. This in itself was the source of great delay, which was much enhanced by the very diffi-

PERSONNEL.

W. G. Beverley, Esq.,	Asst. Supdt.	2nd Grade.
Mr. G. A. Harris,	Asst. Surveyor	1st Grade.
„ W. J. O'Sullivan,	ditto	1st Grade.
„ C. Bryson,	ditto	3rd Grade.

cult nature of the country which, where not covered with forest, is clothed with gigantic tropical grass and reeds, the latter so thick that in clearing a ray they had to be cut one by one as if they were small trees.

(20.) The district officers did not give any assistance, and consequently the party had to struggle against a dearth of local labour, though the villages met with would have been able to supply all that was required without any inconvenience.

(21.) After a careful reconnoissance of the ground, Mr. Beverley came to the conclusion that the only chance of progressing would be got by carrying the Series along the great river, whereby much heavy jungle cutting would be avoided on the one hand, whilst on the other he would escape the excessive demands for compensation which Tea planters and other private owners would have exacted had he kept clear of the river; previous experience had proved that such owners have exaggerated ideas as to the value of their property.

(22.) The heavy smoke from the jungle fires was as troublesome as in previous seasons; and after the middle of January none of the distant peaks were visible even after a sharp shower of rain.

(23.) With a view to assist the party in overcoming the various difficulties that it had to encounter, I restricted the Brahmáputra Series operations as much as possible, transferring Mr. Harris of that Series temporarily, and devoting all spare men, elephants and funds that were available in order to carry on the work of the Assám Triangulation.

(24.) Though so much delayed by having to change all the arrangements of the Series, owing to the impossibility of making use of the hills, Mr. Beverley was able to complete 420 square miles of principal triangulation by a direct advance of 40 miles, the secondary triangulation covering an area of 2,300 square miles.

(25.) One important advantage has been secured by adhering to the course of the river, as Mr. Beverley has thereby been able to fix four (4) of the Revenue Survey Stations, which was satisfactorily accomplished by means of careful observations to heliotropes. This will meet the wants of the Surveyor General who was anxious to have some of the Revenue Survey points in Assám fixed with a view to compiling the Revenue Survey work, which can be now carried out.

(26.) The health of the party was fair and it suffered less from insects than during the previous season.

(27.) Arrangements have been made to strengthen the Assám party still further, and as the Series has now reached the Sibságar district, one of the healthiest in Upper Assám, it is hoped that the triangulation will progress rapidly during the ensuing seasons.

NO. III.—TRIGONOMETRICAL.

NORTHERN SECTION OF THE BANGALOR MERIDIONAL SERIES.

(28.) This party under Lieutenant Rogers took the field early in November, and complete arrangements having been made in the previous season he was able to carry on the observations without intermission until a junction was effected with Sir Andrew Waugh's Southern section of the Great Arc which extends North to Dehra Dun. This junction was effected by the 1st of March. Lieutenant Rogers then took up a Minor Series by means of which he connected Haidarabad and Sikandrabad with the Principal Series. He succeeded in fixing both of these important places.

PERSONNEL.

Lieut. M. W. Rogers, R.E., Offg. Deputy Supdt. 3rd Grade.
Mr. W. C. Price, Assistant Surveyor 2nd Grade.
„ J. Bond, ditto 3rd Grade.
„ C. P. Torrens, ditto 4th Grade.
„ W. Oldham, ditto 4th Grade.

(29.) The country traversed by the Series is hilly and very rocky; 20 miles north of the Kistna a range of hills occurs beyond which the country has a mean elevation of 1,800 feet, and towards Bider the whole country rises again and forms a plateau with an elevation of about 2,000 feet. The greater part of the country is without roads, and the villages appear to be in a state of decay owing, it is said, to the failure of the rains for some years past, but more probably to the conditions upon which the land has hitherto been held a state of affairs which the Nizám's Minister has fortunately already begun to improve and as the new Haidarabad State Railway passes through it, there is now some hope that this hitherto but little known portion of the peninsula will rapidly advance in civilization. Considerable delay was caused by thick jungle in some portions, and from the ground being generally all at nearly the same elevation. In spite of this Lieutenant Rogers made very good progress, completing the Series by a direct advance of 86 miles with 16 principal stations, covering an area of 3,099 square miles. The secondary triangulation covers a further area of 2,136 square miles, a large amount of work which is the more satisfactory as all the points, both those visited and intersected, have had their heights as well as their positions determined.

(30.) In addition to the above Lieutenant Rogers was able to determine by means of Aneroid barometers the heights of a large number of places visited by the party in marching from station to station. These heights were taken by simultaneous observations with two Aneroids from Bangalor to Gutti, Lieutenant Rogers marching in advance with one aneroid and an assistant with another aneroid marching one stage behind him, whereby daily simultaneous differences were determined between the ends of each stage, the aneroid barometers being compared every evening. This is the only system by means of which it is likely that really reliable heights can be obtained from these instruments.

The heights determined are published in the Appendix, and form a valuable addition to the geography of this portion of the country which has hitherto been but little known.

(31.) The assistants suffered from ill health; smallpox broke out in one of the detached camps, and I much regret to record that the wife of one assistant fell a victim to it.

NO. IV—TRIGONOMETRICAL.

MANGALUR LONGITUDINAL SERIES, PARALLEL 13°.

(32.) The Madras Party under Major Branfill, though still suffering from the effects of the previous unhealthy season, took the field early in November. The operations were pushed on with great energy and though there were delays, arising from the approximate series requiring alteration, the very difficult nature of the country and the early setting in of the haze, yet in spite of every thing, very good progress was made. Fifteen principal stations were observed from and the Series was advanced over a direct distance of more than 100 miles. The principal triangulation covering an area of 3,239 square miles and the secondary triangulation a further area of 2,053 square miles. The Series was thus carried over the Western Ghâts, a most difficult range, being, as it is, rugged and in parts so densely covered with forest and jungle.

PERSONNEL.

Major B. R. Branfill,	Depy. Supdt.	2nd Grade.
Lieut. J. R. M'Cullagh,	Asst. Supdt.	1st Grade.
Mr. J. W. Mitchell,	Asst. Surveyor	1st Grade.
„ O. V. Norris,	ditto	2nd Grade.
„ C. D. Potter,	ditto	3rd Grade.
„ E. W. Lasceron,	ditto	4th Grade.

(33). The Tidal operations at Tutukudi (Tutikorin) were completed in a very satisfactory manner. An attempt was made to take another set of Tidal observations at Mangalur, but although Major Branfill devoted a great deal of labor and tried every expedient, he was unable to make any permanent arrangements owing to the nature of the coast which is very exposed; during the

ensuing season a more protected site will be searched for.

(34.) The party suffered severely from fever more especially towards the end of the season.

(35.) From the computations of the previous season's work, it appears that the Anaimudi Peak in the Anaimallei Range has an altitude of 8,837 feet above the Sea, nearly 200 feet higher than the Dodabetta Peak in the Nilgiri Hills, which has hitherto been supposed to be the highest peak in Southern India. In determining the heights of the peaks in the Anaimallei Range a very valuable addition has been made to the geography of India, large portions of that part having hitherto been all but *terra incognita*. A further important addition has moreover been made in the same quarter by means of a Secondary Series extending about 120 miles along the Coast to the south of Mangalur, thus bridging the gap left at this place in Colonel Lambton's triangulation.

(36.) So little being known as to the general levels of the country, arrangements were made for taking a large number of aneroid observations at as many places as possible. Leaving Bangalur the party marched in two portions, for the sake of observing Barometric differences between each stage by means of corresponding simultaneous observations with two pairs of aneroids, the result of which proved highly satisfactory, the closing error being only 7 feet. Barometric observations were also taken daily throughout the season, at 10 A.M. and 4 P.M., by the main party and by two of the Assistants who were working separately: a system which is likely to lead to good results, more especially when any one of the observers happens to be at a point whose height has been trigonometrically determined, as in that case great reliance can be placed on the heights derived from the observations made by the other observers.

(37.) The heights determined from the above will be published as soon as Major Branfill is able to compute them.

NO. V.—GEODETIC.

THE PENDULUM OBSERVATIONS.

PERSONNEL.

J. B. N. Hennessey, Esq., Dy. Supdt. 1st Grade.
Captain W. J. Heaviside, R.E., Offg. Dy. Supdt. 3rd Grade.
Mr. J. W. Macdougall, Asst. Surveyor 2nd Grade.

(38.) On the death of Captain Basevi, R.E., the Pendulum party was put temporarily under the charge of Mr. J. B. N. Hennessey, and although the observations were necessarily suspended, a great deal of extra work devolved on Mr. Hennessey, as to arranging the affairs of the party, sorting the papers of Captain Basevi, examining the instruments and carefully packing them so that they might not suffer in any way from damp, &c.

(39.) It was necessary that every record, which could throw any light on the smallest detail of Captain Basevi's valuable operations, should be preserved, not only as a guide for his successor but also that none of his hard earned results should be lost to posterity: my best thanks are due to Mr. Hennessey by whom this difficult task was most skilfully and satisfactorily carried out. When this most urgent work was accomplished the Assistant with the party under Mr. Hennessey's instructions, took up the reduction of some of the last pendulum observations.

(40.) Subsequently Captain Heaviside was given the charge of the party which he joined on the 20th of April. During the recess he has been diligently occupied in arranging the papers under separate headings, and in making himself acquainted with the methods followed by Captain Basevi in observing and computing out the results. Captain Heaviside has also practised as much as possible

in taking observations and has already attained sufficient knowledge of the work to enable him to commence a regular set of Pendulum observations: in this he has throughout been greatly assisted by Mr. Hennessey. Judging from the progress that Captain Heaviside has made I feel every confidence that he will be successful in taking the farther observations that are required to complete Captain Basevi's work.

NO. VI.—TRIGONOMETRICAL.

BILASPUR MERIDIONAL SERIES.

(41.) This series was extended southwards for a distance of 42 miles by means of one pentagon and two quadrilaterals with one set of Azimuth observations taken at Pathaidi. But little secondary triangulation was done owing partly to the almost total absence of all permanent buildings; the inhabitants in this wild, jungle country being chiefly aborigines living in the rudest huts. Some signs of a more civilized people were seen in the shape of ruined temples &c. supposed to be Buddhist, most of them hidden in dense forest, and none of them being sufficiently conspicuous to be seen from the Survey Stations. The position of the Civil Station of Ráipur was fixed.

PERSONNEL.

H. Keelan, Esq., Offg. Depy. Supdt. 2nd Grade.
Mr. L. H. Clarke, Surveyor 3rd Grade.
„ H. E. T. Keelan, Surveyor 3rd Grade.
„ H. Healy, Assistant Surveyor 4th Grade.

(42.) The Approximate series was advanced about 60 miles, and a junction was effected with the southern section.

(43.) The party generally suffered a good deal from malarious fever.

NO. VII—LEVELING OPERATIONS.

DETERMINATIONS OF ALTITUDE BY THE SPIRIT LEVEL.

(44.) The leveling operations were resumed from the last point laid down at the end of the previous season, *viz.* from Parsoni; and the main line was carried from thence *viâ* Sáhibganj (Náthpur) to Purniah with a branch line to the small Civil Station of Madahpur, and another branch to Kotgauwah and thence by two lines to the G. T. S. marks of Dighi and Rámnagar.

PERSONNEL.

Captain T. T. Carter, R. E., Dy. Supdt. 2nd Grade.
Mr. A. W. Donnelly, Surveyor 2nd Grade.

(45.) A number of permanent points were established near Purniah, at the request of the Collector, in order to serve as checks on proposed leveling operations that are to be carried out by the municipal authorities. A chart showing the points fixed and a memorandum as to their heights was given to the Collector. From Purniah the main line was carried down to Karágolaghát, and thence across the * Ganges to the G. T. Survey Bench-mark at the Pírpanti Railway Station, fixed in 1864 by the main line which passes on to * Calcutta. The junction thus effected shows a total difference of 0·78 of a foot.

(46.) After completing the above, the main line was carried on from Purniah to the G. T. Survey towers at Sonákhoda and Rámganj with which a connection was effected by the end of the field season; this is a most important determination as the two towers mark the ends of one of the initial bases of the Trigonometrical Survey.

(47.) Considerable delay was caused by the want of roads, in one portion the line having to be carried through high grass. There was also a difficulty as to the crossing of the Kosi river and still more as to the Ganges, which was so broad that special arrangements had to be made before the leveling staves could be read off.

(48.) The out-turn of work has altogether been very good, embracing as it does 215 miles of double leveling, during which 7 trigonometrical stations were connected with and 16 bench-marks were laid down with a very much larger proportion of marks on permanent points than usual. I had specially directed Captain Carter to fix more bench-marks, and he has very satisfactorily carried out my instructions. The bench-marks and permanent points are always most valuable as points of reference and checks for local works such as canals, drainage &c., and in the last season's work done by his predecessor there were some unnecessarily large gaps without any permanent mark of the main line of levels.

(49.) Mr. Donnelly held temporary charge of the party until Captain Carter's return from furlough. The arrangements made by Mr. Donnelly were very satisfactory and the work done by him has turned out very good.

(50.) The health of the party was on the whole good.

No. VIII.—TOPOGRAPHICAL.

THE SURVEY OF GUZRAT.

(51.) Major Haig R.E., took over charge of this party on the 23rd September and started for the field on the 23rd of October; operations commencing near Súrat as soon as arrangements were completed.

PERSONNEL.

Major C. T. Haig, R.E., Offg. Dy. Supdt. 1st Grade.
Captain A. Pullan, S.C. „ „ 3rd „
Mr. A. D'Souza, Surveyor 3rd Grade.
„ A. Christie, Asst. Surveyor 1st Grade.
„ C. H. McA'Fee, Asst. Surveyor 2nd Grade.
„ E. J. Connor, „ „ 3rd „
„ J. Hickie „ „ 3rd „
„ G. D. Cusson, „ „ 3rd „

(52.) The topographical operations were diligently pushed on; and the area mapped, *viz.*, 1382 square miles, shows a marked increase on that of the previous season. Every endeavour was made to execute a large area of triangulation for the ensuing season as well as to supply extra points for use during the current season. In all 1036 square miles were triangulated including the Minor series along the River Mahi. The Mahi triangulation had previously progressed very slowly owing to the dense forest and jungle on both banks, which made it very difficult to get long sides; but by adopting smaller sides, and making as much use as possible of the open space of the river itself, the work was brought to a satisfactory conclusion by the end of June. A number of stations of the Súrat city survey were fixed by the triangulation; and Major Haig consequently anticipates that he will be able to prepare a very accurate map of Súrat without much extra labour.

(53.) Many portions of the country being thickly wooded, I directed that a larger amount of traversing should be carried out in such places, the main traverses to start from and close on trigonometrical stations. The necessity for adopting more traversing was evident, because a complete network of triangulation would be very expensive, and even if executed could never supply so many points as a number of main and minor lines of traverses which in their progress would besides determine numerous topographical features which could not be got from a triangulation.

(54.) Major Haig reports favorably of his Assistants who have now all had a good share of experience, and with strict attention to each particular opera-

tion I have no doubt but that a full amount of first-class work will be turned out during ensuing seasons. The training of the native Sub-Surveyors has also received due attention and several of them have already completed a fair share of work.

(55.) Major Haig has shown great tact in dealing with the Baroda Darbár, and by conciliation has prevented all obstruction in the progress of the Survey which is a matter of congratulation, as at one time the opposition of the Native officials seemed likely to seriously retard the operations.

(56.) Altogether, considering that the party is a new one, very good progress has been made, and I feel sure, if it is possible, the general out-turn will be again increased during the ensuing field season, though the party has to work in a very difficult flat country, in parts densely wooded.

(57.) The health of the party has been fairly good, only 2 or 3 members suffering from fever &c., and as Major Haig is well acquainted with the climate of the country I hope the health of the party will be as good in future seasons.

No. IX.—ASTRONOMICAL.

LATITUDE OBSERVATIONS ON THE MERIDIAN OF 75°.

Captain W. M. Campbell, R. E., Offig. Dy. Supdt. 2nd Grade.
Mr. A. H. Bryson, Asst. Surveyor 4th Grade.

(58.) This party resumed operations to the south of Kem H. S. in Lat. 18° 11′. The party started on the 9th of November but observations were not commenced till about 20th December; from the latter date to the 17th of May 7 stations had been selected and observed from, including a second set of observations at one of them, the party during this period having travelled 450 miles by land and 100 by sea.

(59.) The selection of the stations was satisfactorily made, and on the whole they are likely to be as free from disturbance of the plumb line as is possible in such a country.

(60.) The observations were taken with the new Zenith Sector which has worked very satisfactorily; though there is, as in its sister instrument, a tendency to instability shown by gradual change of the zero of levels and microscopes and level of transit axis, a tendency which it is hoped means will be devised to correct: for although it is not likely to affect the observations, as the time occupied in taking a double observation is but 5 minutes, yet it would be as well to perfect the instrument in this respect.

(61.) The capability which this instrument has of changing the zero on its limb in a great measure removed the necessity for taking exact pairs of north and south Stars, as a fresh set of graduations is used for every observation whether of the same Star or not. I accordingly sanctioned Captain Campbell's dispensing with Stars in pairs, though he was directed to use an equal number of Stars north and south of the Zenith and to endeavour to maintain an equality between the mean zenith distance north and south, making it his first object to use Stars depending on the greatest number of observations.

(62.) Hitherto the labor of reversing the Zenith Sectors bodily, has prevented the observers from trying the experiment as it involved taking the instrument entirely to pieces; but Captain Herschel R.E., devised the means of revolving it, all standing, as described in his report and found that it had such a decided effect on the results that it was evidently essential and Captain Campbell accordingly adopted the plan as soon as it was communicated to him.

(63.) The plan of changing the order of position (East and West) of observation with alternate stars, was found to be preferable to doing the same on alternate nights. Throughout the season the Zenith Sector was carried on spring carts constructed by Captain Campbell for that purpose, whereby a considerable saving has been made in the pay of bearers, and not a little delay avoided, as bearers are always difficult to get and keep. The carts have answered their purpose admirably; the instrument having passed safely over some very bad, rough tracks not worthy the name of road.

(64.) Altogether the progress of the party and the use made of the instrument has been very satisfactory.

NO. X.—TRIGONOMETRICAL.

THE BRAHMAPUTRA SERIES.

(65.) The field operations of this party under Mr. Beverley were entirely confined to the approximate operations, as much of the strength of the party as possible being devoted to the Assám triangulation. Five rays were finally cleared; three towers were completed, and a commencement was made with a minor triangulation for the purpose of fixing the station of Maimansinh.

PERSONNEL.

W. G. Beverley, Esq., Assist. Supdt. 2nd Grade.
Mr. C. J. Neaville, Surveyor 2nd Grade.
„ G. A. Harris, Assist. Surveyor 1st Grade.

(66.) As much progress has been made as the means available admitted of, and the whole of the approximate series has been completed with the exception of the building of 4 towers and 5 platform stations.

(67.) More than sufficient stations have been prepared for the ensuing season's operations, and the remainder, noted above, can be built while those to the south are being observed from.

(68.) About 20 per cent of the establishment were generally ill with fever.

NO. XI.—TOPOGRAPHICAL.

THE SURVEY OF KATTYWAR.

(69.) The progress made by this party under Captain Trotter has continued to be very good, though the south portion of the ground surveyed topographically was mostly flat, while in that to the north there was a large amount of detail. Had there not being so much detail in the latter, the party might have turned out even a larger area than it has. It is satisfactory to be able to report that the tálluka boundaries of the ground surveyed were found to have been properly demarcated by the time the party took the field. This is a point which this Department has had the greatest difficulty in getting carried out, not only in Kattywar but in all parts of India. The Civil, Forest Departments &c., ask to have boundaries laid down, but forget that it is quite impossible for this Department to do anything until the boundaries are demarcated in some permanent

PERSONNEL.

Captain H. Trotter, R.E., Depy. Supdt.		3rd	Grade.
Lieut. A. W. Baird, Asst.	„ „	1st	„
Mr. J. McGill, Assistant Supdt.		2nd	„
„ F. Ryall, Surveyor		4th	„
„ J. Wood, „		4th	„
„ N. C. Gynne, Assistant Surveyor		2nd	„
„ T. Rendell, „ „		2nd	„
„ E. N. Wyatt, „ „		2nd	„
„ W. Fielding, „ „		3rd	„

manner, as by pillars, &c. The consequence of neglecting this essential preliminary, is endless trouble and expense: and, in the Survey reported on, it was necessary in previous seasons to send in maps disfigured by undemarcated boundaries.

(70.) The necessity for new maps of Kattywar has been fully proved, and in fact become even more obvious than it was when the work first commenced. On comparing the old maps with the new corrected ones, differences of 1 mile in 5 and even of 1 mile in less distances were found to exist; the lines of watershed and drainage were also found to be entirely incorrect, the old maps being positively misleading. For instance an examination of our new original maps induced the the Agent of the Bombay, Baroda and C. I. Railway to lay out for detail survey an entirely different line from what he originally intended when he had the old maps only to judge from. Colonel Anderson, the Political Agent of Kattywar, is very urgent to get the maps of the country round Rájkot. It is gratifying to learn from these and many other instances that the Surveys of Kattywar and Guzrát are fully appreciated.

(71.) The out-turn of the field season has been 2,036 square miles on the scale of 2 inches to the mile; 1,940 square miles of country have also been triangulated preparatory to being surveyed topographically during the ensuing season; traverses amounting to 779 miles were carried along tálluka boundaries with theodolite and chain, and 156 miles more were executed for the purpose of testing the accuracy of the detail survey.

(72.) The season was a healthy one in Kattywar and there was consequently comparatively little sickness in the field.

(73.) Captain Trotter was fortunate enough to shoot four of the lions that haunt the country: judging from the details given in the Appendix they appear to be formidable animals, though not nearly so troublesome to men as tigers are.

(74.) The material collected for final maps will enable the party to prepare a further instalment of them on the scale of 4 miles to the inch, for incorporation in the sheets of the Atlas of India.

The average number of plane table points fixed in each square mile is a little over ten (10).

(75.) In the area triangulated for next season a point has been fixed in every 2½ square miles, and a height in every 8½ square miles, which is ample to secure all desirable accuracy in the detail and at the same time to illustrate the differences of level.

NO. XII.—TOPOGRAPHICAL.

HIMALAYAN SURVEYS IN KUMAON AND GURHWAL.

(76.) During the recess this party was chiefly employed on the fair maps of the Kosi Valley Survey, which comprise 8 large shaded sheets and the same number of skeleton sheets without shading.

PERSONNEL.

Lieut. J. Hill, R.E.,	Offg. Depy. Supdt.	3rd Grade.
„ H. M. Chambers, R.E.,	Asst. Supdt.	2nd Grade.
Mr. E. C. Ryall,	Surveyor	1st Grade.
„ J. Peyton,	ditto	2nd Grade.
„ W. Todd,	ditto	3rd Grade (on Furlough).
„ J. Low,	ditto	3rd Grade.
„ L. Pocock,	Asst. Surveyor	1st Grade.
„ H. Todd,	ditto	2nd Grade.
„ T. Kinney,	ditto	3rd Grade.
„ E. F. Litchfield,	ditto	4th Grade.

(77.) A second edition of the Guide Map for Masúri and Landaur was also prepared containing all the changes that have taken place in the Sanatarium since the original maps were prepared. A table of distances, an index to all the houses &c., and a number of new heights were added to the map, making this new edition very complete.

(78.) The drawing of the Kosi Valley Maps was necessarily laborious, and several of the Surveyors had to be kept in later than usual, and the party was in consequence not able to finish so large an area as it would have done if a complete season had been available.

(79.) The field work began with an extension of the triangulation of the Mána and Níti valleys that drain into the Alaknanda branch of the *Ganges, a most difficult piece of work, as all the stations of observation were necessarily above the limit of forest, and some were 17,000 feet above the sea. The triangulation in the Mána valley was extended from the Badrínáth Temple to the village of Ghastoli, and the triangulation of the Níti valley was carried up to the Níti Pass on the great Himalayan watershed.

(80.) Three stations were established close to the Níti Pass from which a good view of the Trans-Himalayan range, generally known as the Kailás snowy range, was obtained. In this range 8 lofty peaks were satisfactorily fixed and their heights were also determined; one of these peaks is the sacred Kailás Parbat which has various appellations such as Gang-ri, Garingboche, &c. This celebrated peak had been formerly fixed by Lieutenant (now General) R. Strachey, R.E. from similar points near the Níti Pass, and the present operations by which it has been directly connected with the triangulation of India, prove that his results were nearly correct; the height now established being 22,028 feet, just 28 feet in excess of General Strachey's, and the position given by him requiring no material alteration. The determination of these 8 Trans-Himalayan peaks will be excessively useful in testing and compiling the work of my explorers, who have at various times passed near them and have taken numerous bearings to the most conspicuous, in some cases from points very far to the north and east, beyond the Kailás range where I was naturally anxious to have some check upon their longitudes.

(81.) I have previously dwelt on the difficulties which surveying in the upper valleys of the Himalayas involves; they were as formidable as usual in the present instance, and the success of the Surveyors in overcoming them was not a little due to the cordial assistance rendered to them by Captain Garstin who has the Civil charge of this very wild and elevated tract of British Territory.

(82.) The field work of the season comprised the triangulation of the country east of Naini-Tal, including the hills, as well as the flat portion at their foot known as the Bhábar, up to the Nepal Frontier on the Sardah river. The Topographical work covers a number of mountainous districts north and east of Almorah up to the Nepal Frontier, and also a part of the Bhábar to the south of Naini-Tal. A small portion of very intricate, hilly ground opposite Hardwar was triangulated and sketched. This tract had not hitherto been surveyed as it was originally beyond the boundary of Gurhwal, with which it has subsequently been incorporated. A map of it was required in order to prevent there being a gap between the survey of the hills and that of the plains.

(83.) The triangulation covers an area of 1,862 square miles with a trigonometrical point fixed in every four (4) square miles, and one height in every 5½ square miles, a very liberal proportion for the scale of survey.

(84.) The topographical surveying covers an area of 1,279 square miles including a very large amount of intricate, forest-clad mountains with only one-tenth part actually under cultivation. In addition to this 93 square miles of Nepal were sketched from stations in Kumaon.

(85.) The topographical work was examined and tested in various parts and was found to be accurately delineated and in many cases the rendering is most artistic.

(86.) Four large sheets of the fair maps have been prepared during the

recess and will be published by the end of the year. They are capital specimens of drawing both as regards the hill shading and general execution; the style of the work has undoubtedly been much improved by the experience gained on the large scale surveys of Ránikhet and of the Kosi Valley.

(87.) The party has altogether made very good progress and Lieutenant Hill has fully provided for the ensuing season, there being, with previous years triangulation, ample points for all the topographical work that can be taken up next season.

(88.) The health of the party was good during the field season, but after its return to quarters Lieutenant H. M. Chambers, R.E., died at Masúri; he was a most promising young officer and his untimely death was much regretted by all who knew him.

NO. XIII.—ASTRONOMICAL.

LATITUDE OBSERVATIONS ON THE MERIDIAN OF 78°.

PERSONNEL.

Capt. J. Herschel, R.E., Offg. Depy. Supdt. 1st Grade.
Mr. G. Belcham, Asst. Surveyor 1st Grade.

(89.) Captain Herschel after the recess was employed in taking observations connected with the Solar Eclipse of 11-12 December 1871, and his Latitude observations were resumed as soon as he could get away from the work connected with the eclipse observations. Though delayed by this extra duty Captain Herschel was able, by extreme economy of the time available, and by staying out late in intense heat, to complete all the observations that were required up to Elichpur, his most northerly station being in Lat. 20° 44′. This involved a direct advance of 550 miles, which was largely exceeded by wanderings in the Haidarabad territories where roads are unknown, the country traversed being in most places unutterably stony and unsuited for wheeled carts of any description. In spite of the great distances to be traversed and the small time available, Latitude observations were taken at 18 stations, forming four groups as detailed in Appendix. These groups are at intervals in latitude of from about 1° to 2°, but in several instances observations at intermediate points are available from Colonel Lambton's work, some of which Captain Herschel has reduced and has reason to believe that, apart from constant errors, they are good enough to be included. The Latitude observations for the Arc from Cape *Comorin in lat. 8° 13′ to Kaliánpur lat. 21° 7′ may be considered complete, as all that is now necessary is to get the geodetic values of the stations of the last two groups which will be completed early in the next field season.

(90.) The principal stations at 3 of the new groups, were also stations of the late Captain Basevi for his Pendulum observations for the determination of the local force of gravity.

(91.) As stated in Captain Herschel's report for last year, he had reason to think that a peculiar source of error existed in the levels of the Zenith Sector; being unable to account for it, he devised a method for reversing the instrument bodily. This was ingeniously effected by introducing a small metal button under the centre of the instrument after prizing the latter up on one side with a lever. On lowering the instrument on the button a condition of unstable equilibrium was obtained in which this heavy instrument could be turned round, so to speak with a finger, with perfect safety, the feet just grazing the stone slab on which the instrument stands—a method which proved very satisfactory and was as before stated subsequently put into practice by Captain Campbell with the other sister Zenith Sector. At first Captain Herschel thought that this reversal would eliminate

a constant error, which was apparent in the first case, but subsequent experience shows that the effect is barely traceable, and there now seems to be little doubt but that the errors detected are due to the position of the bubbles in the levels. These errors on the whole are insufficient to justify any alteration of previous results; but the system of reversal will be continued, and in order to nutralize the irregularity in the levels, their readings will be purposely and frequently altered during the course of the work, and a re-adjustment of level will be made, say every hour, as a part of the routine.

(92.) The results as far as computed, give farther evidence as to the great uncertainty of local attraction. Between the Honúr group in lat. 14° 54′ and the Darúr group in lat. 16° 12′, being a difference of only 1° 18′ in latitude and 35′ in longitude, *i.e.*, 98 miles, the change in the local disturbance is no less than 8 seconds; and, as the errors of measurement cannot possibly account for more than a small fraction of this amount, there seems no doubt but that the attraction is disturbed in a very irregular way. The Honúr and Darúr groups appeared to be both as free from apparent abnormal causes for irregularity of attraction as they well could be, and yet the change in disturbance shows the largest deflection that has hitherto been observed in India, which may not be directly attributed to mountain masses.

(93.) The amount of work done has been very large and is highly creditable to Captain Herschel. As a rule from 30 to 35 stars were observed each night; and, bearing in mind that at every station and indeed every night almost the meridional direction had to be sought out by transits, and adjustments had to be repeated, before the regular work was commenced, it is easy to understand how harassing the work must have been with the temperature at from 98° to 105°. Notwithstanding the hard work and the exposure towards the end of the field season the health of the party was on the whole very good.

(94.) Captain Herschel's detailed report contains various other particulars that will be interesting to all who study questions into which the variations of density in the crust of the earth enter.

NO. XIV

THE COMPUTING OFFICE.

(95.) In the computing office Mr. Hennessey has continued the calculations of the Sironj-Chach Quadrilateral so as to complete the triangulation; this involved a large amount of computation, chiefly in connection with the auxiliary principal stations, no less than 268 triangles entering, (in groups of 2 and upwards), into 110 figures were made consistent by the method of least squares. So that the whole mass of this extensive work, which forms the basis of the Geodesy and Geography of northern India, has now been reduced by the most accurate of modern processes. Besides the above special work a very large amount of ordinary computations were performed as detailed in para. 3 of Mr. Hennessey's Report.

PERSONNEL.

J. B. N. Hennessey, Esq., Depy. Supdt 1st Grade.
W. H. Cole, Esq., M. A., Asst. Supdt. 1st Grade.

Computing Branch.

Mr. C. Wood, Surveyor 3rd Grade.
„ H. W. Peychers, Asst. Surveyor 1st Grade.
Bábu Gunga Pershad.
„ Cally Mohun Ghose.
„ Kally Coomar and 9 other native computors.

Printing Office.

Mr. M. J. O'Connor.

(96.) A general plan for reducing the secondary triangulation has been prepared in accordance with what has been done for the principal work in the Sironj-Chach Quadrilateral; care has been taken to elaborate a scheme which avoids redundant calculations while securing the full utility of the secondary work, which is becoming more valuable every year for new large scale surveys required for railways, roads, canals &c. Experiments have been made with the new plan and it promises to do what is required with a minimum amount of labour.

(97.) A large amount of the computed results have been compiled for the press, sufficient to cover about 450 quarto pages. In addition a great quantity of data has been compiled and examined for the numerical charts, of which no less than 30 large sheets were prepared, involving months of laborious work which requires the exercise of the greatest vigilance in order to prevent errors.

(98.) The measures for the protection of stations have been steadily persevered with, a reference to Mr. Hennessey's report shows what a large amount of work this involves.

(99.) Besides the above regular work of the office, various other important duties have been discharged by Mr. Hennessey, amongst which may be mentioned the preparation for the press of 1,143 pages of printed matter, mostly quarto size, including 547 pages for the new volumes of the "Account of the Great Trigonometrical Survey"; also the supply of special data to 23 officers.

(100.) Mr. Hennessey also superintended the Photo-zincographic and Drawing branches, the operations of which are detailed below.

I have elsewhere referred to the valuable services of Mr. Hennessey with the Pendulum Party.

Total Eclipse of the Sun, 11-12th December 1871.

(101.) Mr. Hennessey was selected to assist in the observations of the Total Eclipse of the sun which occurred on the 11-12th December 1871. There he rendered very efficient aid and was more especially successful in photographing the eclipse, securing no less than 6 excellent photographs during totality. These photographs have met with deserved commendation from competent authorities in England, and it is not too much to say that they are on the whole superior to any that have hitherto been produced in any part of the world. This was due to Mr. Hennessey's skilful arrangements and to the judgment he exercised in varying his programme on finding what a peculiar state of atmosphere he had to deal with, mist of a varying density having unfortunately prevailed during the whole eclipse.

(102.) Mr. Hennessey gives various interesting extracts from his own report as to the eclipse and also some from Colonel Tennant's report as to the observations generally.

(103.) Altogether Mr. Hennessey has been very fully employed and very great credit is due to him for the efficiency to which the various branches under his orders have attained owing to his skilful and unwearied supervision in all matters.

(104.) Mr. Hennessey has been ably seconded by Mr. W. H. Cole, M.A. who is now competent to assist in all matters, and also to originate valuable projects for the prosecution of the work, whereby his assistance has become doubly valuable.

NO. XV.

CARTOGRAPHY, PHOTO-ZINCOGRAPHY &c.,

Drawing Office.

Mr. G. W. E. Atkinson, Surveyor 4th Grade.
5 Native Draftsmen and 23 Apprentices.

Photo-zincographic Office.

Mr. C. G. Ollenbach.
" C. Dyson.

(105.) The Drawing Office has, as before, been chiefly occupied with the preliminary charts of triangulation and the charts of levels, the following charts having been prepared for photo-zincography, viz., 23 preliminary charts of triangulation, of which the majority have already been published, besides various other triangulation charts which have been prepared in manuscript only for

the use of government officials; 4 sheets of charts of levels have been completed and many more are in course of preparation. An index to the level sheets has also been published, so that officials may at once be able to see whether the materials in their offices can in any way assist the completion of these most useful charts. Numerous maps and reductions have been prepared for incorporation with the level sheets and various others for the use of the Irrigation Department.

Maps for the use of the Camp of Exercise.

(106.) A map of the country round Dehli was compiled with various plans of the city and fortifications on a larger scale for the use of the Camp of Exercise during 1871-72. Experiments were made as to the most convenient form for issuing such maps for use with troops in the field; some copies were printed on water-proof india rubber cloth, on white cloth, and on several kinds of paper, printing being applied on both sides. These were put up in various forms and the conclusion arrived at was that a roll with a couple of elastics attached was the most handy, as it could be carried in the holster. The white cloth promises to be the most serviceable for although the maps on India rubber came out beautifully and were all but indestructible, they were too heavy for general use, and it is probable that they might be unpleasant to handle during great heat. As to paper, some on ordinary thick and thin drawing paper will always be required for office use, with an army, but the maps on bank-post paper were found to be very clear and to stand a large amount of rough handling, though of such nice light material, and on the whole this is probably the most serviceable paper that has hitherto been tried: some farther experiments are being made and I hope that an indigenous material will be found suitable. The results of the experiment will be published hereafter. The printing on both sides of the cloth or paper answered very well even with the thinnest, viz., the bank-post, the maps being as clear as could be wished. Experiments were, however, made by printing the subordinate map at the back in blue or brown, and I think some small advantage was thereby gained on the thinner material. When the portability of the maps is so desirable as during a campaign the advantage of using both sides of the material is obvious and I think should be adopted in future. It may be noted here that cloth maps are perhaps better adapted for use on horseback, many horses objecting to the rustling of paper. Probably a few copies on water-proof cloth would be found useful for an expedition during the rains when every other material is apt to be damaged by the damp. This map was drawn and printed in little more than six weeks, and I need hardly point out how advantageous it is to be able to print a map so quickly; a similar map during the Mutiny would have been of immense advantage but this office had not then got the means of doing anything of the kind.

Route Maps.

(107.) Three sheets of the Maps of Routes in northern India were completed and the 4th was commenced; this compilation has involved a very great amount of close examination and careful selection so as to include every thing useful that the scale would admit of without overcrowding. The maps include my former Kashmir Route Map, with considerable extensions and additions on both sides of the frontier. The additions in *Kumaon and *Gurhwal are more numerous than in any other part. Details as to the routes in the Western Himalayas have been printed to accompany these Route Maps, these details give the distances, heights &c., for the use of travellers who are constantly applying to this office for such information, and it is hoped that with the polymetrical tables attached to them they will supply all that is required.

Trans-Frontier Maps.

(108.) A commencement has been made with a series of Trans-Frontier Maps based on the operations of the Great Trigonometrical Survey and on the explorations made by British and Asiatic explorers from the side of India, more especially on those recently made in connection with this survey by Asiatic explorers. These maps it is hoped will prove useful in studying questions connected with any part of our extensive frontier or with any of the foreign territories lying beyond it. One sheet is now ready for the press and 3 others are in course of preparation.

(109.) A few other original maps and compilations of general interest have been prepared and published, and the Drawing Office has been busily occupied; the amount of work turned out, under Mr. Atkinson who has supervised it, is very satisfactory. The quality of the work has been steadily improving and I am hopeful that with more experience Mr. Atkinson will fully maintain the reputation of the office.

(110.) By the photo-zincographic process 16113 copies of charts, maps and diagrams have been printed of which 1703 have been coloured by hand, for issue to government officials and for sale to the public, and 13655 copies of forms for calculation and office work have been printed by zincography for the use of this department. Though the total number of prints of all sorts is about the same as last year a far larger amount of the elaborate kinds of work—maps and charts—has been performed, both these sorts of works are photo-zincographed.

(111.) Mr. Duhan resumed charge of his office as personal assistant in September 71, and has discharged his various duties entirely to my satisfaction.

Mr. H. Duhan, Surveyor 1st Grade. Personal Assistant.

NO. XVI GEOGRAPHICAL.

TRANS-HIMALAYAN AND TRANS-FRONTIER EXPLORATIONS.

(112.) Explorations have been continued in various directions on our western, northern and north-eastern frontiers. On the whole great progress has been made and one continuous line of explorations beyond the frontier has been carried right round India. The route traversed, starting from Sindh, goes to Khelát in Beluchistán and thence by Kandahár to Kábul. From Kábul it crosses the Hindu Kush mountains to Badukshán and thence up the head waters of the Oxus and across the great Pámir Steppe to Káshgar and Yárkand in Eastern Turkestán. From Yárkand the explorations follow the route to the Kárakoram pass, and thence the connection is continued by the regular operations of this survey to the Pangong lake, and south to the Indus, where that river first enters Ladák near Demchok. From Demchok the line of the explorations is carried up the Indus and its large branch the Gartung-chu to Gartok and thence across the Kailás range to the Mánsarowar lake. From the Mánsarowar the line is continued across the *Himalayas, then down the course of the great Nári-Chu or Sang-po river (the Bráhmáputra) to Shigatze and thence to Lhása the capital of Great Tibet. This line with its branches is about 5000 miles in length and is connected with British India by numerous cross lines, the details of which have from time to time been published in the reports of the Great Trigonometrical Survey. It must be remarked that these routes were all at great elevations above the sea, more than half being at over 12,000 feet, a fact which has of course added very much to the difficulties of exploration.

(113.) Very great progress has been made with a second line, inside the above line, in such places as it is required, the results of which will be published before long, though it is not convenient to do more than refer to it until the work is completed.

(114.) A commencement has been made with a third line of explorations exterior to the first line referred to, and at a very considerable distance beyond it; some progress has already been made with it, the first link being that from Yárkand to Khotan, determined by Mr. Johnson's exploration, and thence across the lofty Lingzithang plateau to the Pangong lake. From the Pangong our explorers have extended the line by a traverse to Rudok, the capital of the Chinese districts of Pangong &c., and thence, over the very elevated plateaux north of the great Aling-Gangri peaks, to the Thok-Jálung gold field, passing through a succession

of gold and borax fields. From Thok-Jálung the line has been extended south-east through Májin to the Shellifuk lake, north-east of the Great Kailás Parbat over the most elevated plateaux in the world; the explorers having been for months at over 15,000 feet above the sea. This portion of the outer line is connected with the Mánsarowar lake. Farther extensions have been made to the west and north of Lhása, and I trust eventually that a junction will be effected between this and the portion near Shellifuk and thus open out a large portion of the geography of Central Tibet. On the west some extension has already been made with this outer line beyond the Oxus and I am hopeful that more will be forthcoming. In this report details are given with respect to one of the connecting lines between the inner and middle line of explorations, *viz.*, between Dárjiling and Shigatze in Great Tibet on the one side, and between Shigatze and Nepal on the other. These lines of exploration open out the geography of a very large tract of country as to which we previously had but the vaguest conjectural indications. The routes may be described as going right round the great Mount Everest, penetrating on the north, to the Sang-po or Bráhmáputra River and thence south-west over the well-known Tingri maidán, the most extensive plateau on the south of the *Himalaya watershed that is drained by streams which flow direct into India.

(115.) From Tingri the line passes to the west of Mount Everest, and again connects with the work brought up from India.

(116.) The greater part of this work was done by one explorer; on a reference to the map it will be seen that his route for some distance corresponds at points with Doctor (Sir Wm.) Hooker's route west of Dárjiling, the new ground commencing from his most north-westerly points near the Wallanchun and Kanglachem passes, embraces a portion of the great eastern branch of the Arun river, then passes a large lake of which we had previously heard though its position has never, as far as I know, even been indicated on any map. The position of a number of peaks, north of those which are visible from the side of India, have been determined. The country has of course been crossed previously by the Ghurkas, Niwars and other natives of the adjacent countries, but as far as I know has never been even seen by an European. Amongst other places this route has fixed the position of the celebrated Sakya monastery second only to that of Tashi Lumbo. The route traversed is 844 miles in length of which 550 miles may be said to be over entirely new ground and the remainder, though close to a line which at least one European has gone along, has never been regularly surveyed before. This exploration with its bearings &c., opens out the geography of nearly 30,000 square miles of what has hitherto been all but *terra incognita*, it more especially elucidates the geography of the basin of the Arun or Arun Kosi river, the largest feeder of the great Kosi river, which drains the whole of Eastern Nepal. The courses of its upper feeders have been hitherto a puzzle to geographers.

(117.) The routes give an independent determination of the longitude of Shigatze and prove that the value which I adopted for that town, based on Turner's Route Survey, was a very close approximation. This point was fully discussed in my Trans-Himalayan report for 1865-67 on the Chief Pandit's exploration from the Mánsarowar lake to Lhása at page x, and it is gratifying to find that my reliance on Turner's work was not misplaced.

(118.) The explorer took latitude observations at 11 points upon which the work depends, and he determined the height of 31 places. His work has stood all the usual tests of comparison satisfactorily, and as it includes a considerable number of peaks &c., on both sides of his route: I think it will prove a valuable addition to the trans-frontier geography of India.

DEHRA DUN,
November 1872.

T. G. MONTGOMERIE, MAJOR R.E.,
Offg. Supdt. Great Trigonometrical Survey of India.

Abstract of the out-turn of work executed by the Great Trigonometrical Survey Parties, during the Official year 1871-72.

Description of Details.	1 Brâhmaputra Series. 24-inch Theodolite.	2 Eastern Frontier Series 14-inch Theodolite.	3 Bider Longl. Series. 36-inch Theodolite.	4 Biláspur Mdl. Series. 24-inch Theodolite.	5 *Bombay Party. 24-inch Theodolite.	6 *Madras Party. 24-inch Theodolite.	7 Guzrat Survey. (Topographical.)	8 *Kattywar Survey. (Topographical.)	9 *Kumaon & Gurhwal Survey. (Topographical.)	Total.
Number of Principal Stations, newly fixed,	...	5	13	8	15	10	...	...	...	51
Number of Principal Triangles, completed,	...	5	18	11	19	11	...	...	...	64
Area of Principal Triangulation, in square miles, ...	...	420	3041	511	3099	3239	...	...	...	10,310
Lengths of Principal Series, in miles, ...	...	40	128	42	86	100	...	...	...	396
Average Triangular error, in seconds, ...	...	2·88	0·62	0·39	0·59	0·33	...	...	...	...
Average Probable errors of Angles, in seconds, ±	...	0·78	0·28	0·25	0·17	0·14	...	...	...	...
Azimuths of verification, ...	...	...	1	...	1	1	...	...	...	3
Number of Secondary Stations whose positions and heights have been fixed, ...	...	35	7	13.	23	55	142	221	287	783
Do. of Secondary Stations whose positions only have been fixed, ...	...	...	...	5	...	...	...	739	111	855
Do. of Secondary Triangles of which all 3 angles have been observed, ...	...	4	1	15	26	6	213	188	80	533
Area of Secondary and Minor Triangulation, in square miles, ...	...	2300	2109	134	2136	2053	1036	1900	‡1862	‡13,530
Number of Points fixed by intersection, but not visited, ...	...	47	22	5	74	49	535	?	302	?
Length of boundary lines and check lines surveyed, in miles, ...	...	...	...	...	...	...	595	935	78	1608
Area Topographically surveyed on scale of 1 inch = 1 mile, in square miles,	...	...	...	...	...	...	...	...	†1279	†1279
" Topographically surveyed on scale of 2 inch = 1 mile, in square miles,	...	...	...	...	...	...	1382	2036	...	3418
Number of Revenue Survey Stations and boundary pillars, fixed, ...	...	4	...	1	...	...	...	...	15	20
Do. of Principal Stations selected in advance, ...	2	6	18	6	...	3	...	...	...	35
Lengths of Approximate Series, Principal, in miles, ...	...	...	115	60	38	28	...	...	...	241
Number of Towers, constructed,	3	...	...	6	2	1	...	...	...	12
Do. Platforms constructed for Principal Stations, ...	...	...	14	4	9	11	...	...	...	38
Do. Platforms constructed for Secondary Stations, ...	...	...	...	12	8	...	...	...	...	20
Do. Miles of Rays cleared, ...	62	40	...	113	18	5	149	...	...	387
Do. Miles of path-way made,... ...	...	...	99	...	5	24	...	...	...	128
Do. Hill tops cleared of forest and jungle,	6	2	15	9	11	10	...	...	...	53
Do. Principal Stations whose elements were computed, ...	...	5	...	...	11	7	...	...	...	23
Do. Secondary Stations whose elements were computed, ...	...	51	...	...	42	48	?	...	533	...
Do. Preliminary Charts of Triangulation,	...	1	...	...	1	1	...	...	...	3
Do. Principal Stations placed under official protection, ...	3	...	...	8	9	8	...	...	...	28
Do. Stations protected and closed, ...	3	...	...	9	10	8	...	...	...	30
Length of Line by double leveling, in miles,	...	...	...	...	...	...	...	...	...	245
Number of points whose heights were determined by Spirit Levels, ...	...	...	...	...	...	...	...	..	...	190
Number of points whose Latitudes have been determined Astronomically, ...	...	...	..	...	...	...	...	...	...	25
Length of Route Survey, in miles, ...	...	...	...	...	...	...	...	...	...	...
Number of Stations at which complete Tidal observations, have been made, ...	...	...	...	...	...	...	...	...	...	1
Area of unknown territory explored, in square miles, ...	...	...	...	...	...	...	...	...	...	...

‡ Including 302 Square miles of Trans-Sutlej Minor Triangulation.

† Excluding 93 Square miles of the Nepal border sketched from Kumaon.

APPENDIX.

EXTRACTS FROM THE NARRATIVE REPORTS

OF THE

EXECUTIVE OFFICERS IN CHARGE

OF THE

SURVEY PARTIES AND OPERATIONS.

Rules for pronouncing Indian proper names.: *a* has a variable sound as in *woman*, *rural*, *poltry*; *á* as in *tartan*; *i* as in *clique*; *í* as in *ravine*; *u* as in *bull*; *ú* as in *rural*; *o* as in *note*; *e* as *a* in *say*; *au* as *ou* in *cloud*; *ai* as *i* in *ride*; *g* as in *gong*; abad as ábád; bazar as bázár. Exceptions to spelling by rule are indicated thus *Calcutta, *Calicut, &c

Extract from the Narrative Report—dated 16th July 1872—of W. C. ROSSENRODE, ESQ., Deputy Superintendent 3rd Grade, in charge Bider Longitudinal Series.

(2.) In compliance with Departmental Order No. 39, dated 31st August 1871, I assumed charge of the Bider Longitudinal Series, G. T. Survey, on the 6th November and the party took the field on the 20th December 1871.

(3.) During the recess of 1871 the party was engaged in the following computations which, owing to the continued illness of Messrs. Bell and Wrixon, progressed very slowly,—

Spheroidal Excesses computed in duplicate	5
Weights and Reciprocals of Observed Angles in duplicate	17
Computed angular corrections to Pentagon in duplicate	1
Number of Principal Triangles computed in duplicate	5
Number of deductions Latitudes, Longitudes and Azimuths of Principal Stations in duplicate	10
Number of deductions of Heights of Principal Stations in duplicate ..	10
Number of Secondary Triangles determining 14 intersected points in duplicate	26
Number of Latitudes, Longitudes and Azimuths of Secondary Stations in duplicate	28
Number of Heights of Secondary Stations in duplicate	1
The Preliminary Charts of the Bider Longitudinal Series for seasons 1869-70 and 1870-71	2

(4.) The country through which the operations were carried on was hilly throughout, very wild, difficult and unhealthy. The jungle was dense, the passes lengthy, tedious, steep and stony. In ascending and descending them, the pack bullocks (the only available carriage in this district) were mostly disabled in the early part of the season and were completely unserviceable on closing work. From sore feet and sore backs many died and others being unable to follow the camp were abandoned. The scarcity of rain and the failure of the crops greatly enhanced the difficulties; for supplies of every description had to accompany the camp and provisions had to be collected and brought from long distances. A depôt was established at each station for the use of the camp during its stay there, and the remainder sufficed for the stages between it and the next station. The arrangements for provisioning the party were good and no inconvenience was experienced during the whole of the field season. Owing to the drought, the streams which were abundant the previous season were found dry in many places.

(5.) Mr. Henry Beverley has in his Narrative Report of last season, 1870-71, described the country so carefully and minutely that I can add nothing more to it, for the country in which he worked was similar to that in which I was employed,—in fact, it was a part of the same country presenting the same features and peculiarities of configuration.

(6.) The sides of the triangles were mostly long. During favorable weather no detention occurred. I completed one station in December and five stations, including an Azimuth, in January. Marching was tedious and trying, and much time was lost in crossing over the hills through the (ghats) passes. It occupied my camp 8 days to reach Páncha Hill Station from Kaurálbiding Hill Station, the direct distance being only 29·3 miles; each stage was from 12 to 16 miles and two of these were of greater length. The tortuous paths strewed with stones over the roughest ground traversed by man and beast was most trying to all in camp and more especially to the carriers of the great Theodolite, who although assisted by coolies could barely make much progress in ascending and descending these stony hill paths. To clear these paths of stones and rocks would cost immense sums of money and occupy months of labor. They were therefore merely widened for the great Theodolite by the jungle being cleared and by the removal of large rocks, or, if these could not be removed, by avoiding them.

(7.) The great Theodolite could not on two occasions come up, and the men had to bivouac in the jungles and join camp the next day. As has already been said much time was lost in marching from station to station owing to the circuitous routes we had to adopt to take advantage of the easiest known passes to cross over these mountain ranges. These delays would have been greater had not Mr. Beverley furnished me with the routes from station to station, and how they should be visited with reference to one another. He had been over the country and was able to give me the most direct routes to each station of each figure and all unnecessary detours were thus avoided by visiting each station according to the programme provided by him.

(8.) About the middle of February the jungle was fired in all directions and smoke spread gradually. The haze set in about the same time and the atmosphere became daily more unfavorable for observations, until the whole country was enveloped in haze and smoke, and nothing could be seen. Our luminous day and night signals could not penetrate this thick atmosphere.

(9.) From the 23rd February to the 24th March, I was detained at Munas Hill Station for the observations which were completed in a month during occasional breaks of favorable weather. At the above station not a single angle to lamps was observed. At the next station, Báli, I was again detained for nearly a month: a few showers of rain accompanied by storms, two of which were very severe, enabled me to complete my observations and released me from this station.

(10.) The above two stations furnished the base for the Southern Section of the Biláspur Meridional Series; and on completing them the junction with the Coast Series was accomplished.

(11.) I proceeded to Tulsi Hill Station, the centre of the first pentagon of the Biláspur Meridional Series Southern Section. Occasional showers of rain enabled me to progress rapidly with the final observations which terminated at Bárdwár Hill Station on the 4th May 1872. There was sickness during the whole field season, but at Bárdwár 10 and 12 men were daily prostrated with fever; I therefore closed work and returned to recess quarters. My second attack of fever occurred here and I returned to Wálter by dák and was seriously indisposed on the journey; since my arrival I have had frequent returns of fever.

(12.) There was very great sickness in camp this field season, not a single man in the whole party escaped from fever. My first attack occurred at Kálingkonda Hill Station, my third Station in January, while observing an Azimuth there. I persevered with the observations notwithstanding my daily bouts of fever. Fortunately Mr. Beverley was in camp and assisted me both in the observatory and office, and I am greatly indebted to him, for had he not been present, the star could not have been observed by me single-handed owing to the bad state of health I was in at the time.

(13.) Sickness reduced the strength of my native establishment considerably, and so crippled me that I had to carry the stand and telescope of the great Theodolite and most of the Government property on coolies. Some of the sick men were useless during the whole field season and were sent home when I returned to recess quarters. Those men who returned with me comparatively well have, since coming in, had frequent relapses of fever, and most of them have enlarged spleens and are still in hospital under treatment. There were no casualties in the field, but since returning to Wálter 5 deaths have occurred, 4 from fever and 1 from dysentery.

(14.) The operations have entered the Bastar and Jaipur states, and I believe the country will improve as we proceed northwards, and there will not be so much sickness during the ensuing season in the more open country through which the operations will be carried on.

(15.) Wild animals are very numerous in the tract triangulated last season, and tigers are most destructive: villages have been deserted and some of the passes have been closed owing to their depredations. While engaged in observations at Kaurálbiding Hill Station, I ordered a good portion of my camp to proceed to the first stage *en route* to Páncha Hill Station and to await my arrival there. These men were kept at bay for hours by a tiger which I was informed took possession of the road that had been cut for the great Theodolite. The camp moved on in a body when he had retreated into the jungles after the men had yelled and shouted for hours. Often the villagers cautioned us not to proceed by paths which were in possession of these man-eating tigers, which, waiting their opportunity, carried off numbers of people as they, unsuspicious of danger, travelled on the path.

(16.) The inhabitants are few and the hamlets very distant from one another. Very few large villages were met with. Frequently a single large hut was seen; its occupants consisted of fathers, sons, and grandsons with their wives and children. A spring of water or a stream, a small cleared patch of ground for cultivation of grain, with a few lime, orange, jack and mango trees were sufficient to satisfy the wants of the family. The inhabitants are steeped in ignorance and vice: men, women and children drink toddy from the sago palm, or distil spirits from the Mana flowers which they also dry and retain for food. They drink to excess, are very poor and wear a rag 4 inches wide and two feet long to hide their nakedness. Among some of the hill tribes nude figures are the rule and not the exception. The authorities have tried to civilize them by distributing cloth among them but they will not clothe themselves.

(17.) Owing to the party being short-handed, by the absence of Mr. Bell on furlough and the crippled state of my native establishment during the entire field season from sickness, very little secondary work has been done: what has been accomplished has been executed by me

with the great Theodolite. A great deal more could have been done had I men to renew the hill marks of the Topographical Survey which were consumed by fire and had the weather been favorable. Many of the poles of the Topographical Survey, indicating their stations, were observed from one station only, the weather becoming unfavorable they could not be seen from Munas and Báli Hill Stations when the jungle was fired and the haze set in.

(18.) I was not unmindful of the importance and value of Secondary work in connection with our principal operations. I trained Mr. Wrixon for the work and detached him on the 24th February to lay down Jaipur, but want of experience and bad weather prevented his completing the Secondary work I assigned to him.

(19.) Mr. Henry Beverley, Surveyor 1st Grade, was detached on the 17th January after the Azimuth observations at Kálingkonda Hill Station to extend the Approximate operations. He revisited Bárdwár and Saikárpan Hill Stations which he had fixed the previous season, and continued his operations and connected with the stations of the Northern Section Bilaspur Meridional Series Malewa and Bamnai. The fruits of his labors are 16 stations selected, the hills cleared of jungle and platform's constructed. His zeal and energy have been most conspicuous, for notwithstanding the great sickness among his men he pushed on until he completed his portion of the work and effected a satisfactory connection with Mr. Clarke who carried on the Approximate Series of the Northern Section. Mr. Beverley was delayed by bad weather, and as the season was far advanced and the men of his establishment were prostrated with fever he could not undertake Secondary work. He joined me at Tulsi Hill Station and remained in camp assisting me at two more stations Pothdongri and Saikárpan; he was again detached to alter a compound figure into two single ones. As the whole of the Approximate work has been completed, Mr. Beverley can, the next season, be employed uninterruptedly on Secondary operations.

(20.) Mr. E. P. Wrixon, Assistant Surveyor 2nd Grade, was employed in recording observations and in current office duties until the 23rd February. He was detached on the 24th of the same month to lay down the town of Jaipur by a series of Minor Triangulation, and after that to lay down the town of Bastar. Owing to the hazy weather during the latter part of February, the whole of March and the first week in April, he was unable to do any work as he was aiming to connect Jaipur with large triangles. This is the first time Mr. Wrixon has been detached on Secondary Triangulation, I trust his want of experience combined with the unfavorable weather which set in immediately after he was detached will plead for him for the small out-turn of work. Mr. Wrixon twice suffered from fever in the field and his detachment suffered greatly from repeated attacks of fever.

(21.) In conclusion I have to refer to the Hospital Assistants who were with me during the last field season. The first-class Hospital Assistant who accompanied me from Wálter was an experienced, attentive man and fully competent to take charge of a large camp. He was however old and infirm and was very soon disabled from repeated attacks of fever. A second-class Hospital Assistant succeeded him; this man had been employed under Colonel Saxton, Deputy Superintendent Topographical Survey, in charge No. 3 Party. He was acquainted with the country and he could not help joining when posted to the Bider Longitudinal Series, but he was so intimidated that shortly after joining he complained of illness. He travelled in a dúli and was of very little use during the remainder of the season. He was always complaining of his own illness and the sickness in camp, and was continually urging me to close work after the 1st April. On the plea of ill health he was inattentive and careless. He went to hospital shortly after my arrival at Wálter, and has obtained leave on Medical certificate for 7 months. The third-class Hospital Assistant doing duty at present with me promises well.

(22.) The following is the out-turn of work executed during the field season :—

Principal stations newly fixed	13
No. of Principal Triangles completed	18
Area of Principal Triangles in square miles completed ..	3041
Length of Principal Series in miles	128
Azimuth of verification	1
No. of Secondary Stations whose positions and heights have been fixed	7
No. of Secondary Triangles of which all three angles have been observed	1
Area of Secondary Triangles exterior of Principal Triangulation, square miles	2109
No. of points fixed by intersection but not visited	22
No. of Principal Stations selected in advance including Malewa and Bamnai of Northern Section, Bilaspur Meridional Series ..	18
Length of Approximate Series in miles	115
No. of Platforms constructed for Principal Stations ..	14
No. of miles of pathway made	99
No. of hill tops cleared of forest and jungle	15
No. of Stations protected and closed	none

The area of the Principal and Secondary Triangles completed during the field season 1871-72 is 5150 square miles, at a cost of Rupees 34,768-12-8, which gives a rate of Rupees 6-12-6 per square mile.

Extract from the Narrative Report—dated 12th July 1872—of W. G. BEVERLEY, ESQ., Assistant Superintendent 2nd Grade, in charge of the Eastern Frontier Series (Assam Valley Triangulation).

(2.) The party marched from Gowhatty on the 17th December viâ Naugong, and proceeded on to Kankochan Hill Station where I arrived on the 2nd January.

(4.) At the close of last season there were only two stations selected and built in advance, and although Mr. O'Sullivan had laid out the Khelibúíshon pentagon, he was doubtful whether the stations of Cheníábúíshon H. S. and Sapanajung H. S. as then selected, were mutually visible, as he had not been able to determine that point finally the previous season from the very unfavorable weather at its close. The rejection of one of these points and the conversion of the figure into a series of simple triangles seemed also probable. I therefore waited at Kankochan H. S. until Mr. O'Sullivan had decided on the position of the forward station Cheníábúíshon H. S. which he did by the 9th. The principal observations at this station being completed I marched on to Khelíbúíshon H. S. and having taken all the observations there, I proceeded to Chenghchishon H. S. where I arrived on the 24th January. I was detained here four days waiting for the signal at Sapanajung H. S. On the evening of the 27th I received a letter from Mr. O'Sullivan informing me that he had at last been compelled to reject that point and I closed at this station and left on the 28th January.

(5.) I had desired Mr. O'Sullivan to reject Sapanajung H. S. in case he should not be able to see it from Cheníábúíshon H. S. as the best part of the field season had already gone and much time had already been lost. The station of Cheníábúíshon H. S. is situated on the outermost of a series of parallel ridges of uniform height and densely wooded, the site selected was the only one which could command a view of the plains to the North and East and also be visible from the back stations, hence it was not considered advisable to remove it, as it would not only have created delay, but involved re-observing the angles at two stations, but above all made it difficult to carry the series into the plains which it had now become necessary to do.

(6.) Mr. O'Sullivan had reported on his return to recess quarters at the close of the field season of 1870-71, that he had received reliable information that the Lotha Nágás across the Dhunsiri River would prevent the entry of any Survey parties into their district. As this information had not been alluded to in the General Report, nor in the instructions for next season's work, the method of procedure for carrying the triangulation into the plains and other considerations involved, were not discussed by me at Head Quarters with yourself. I was informed by the Commissioner of Assam when I requested his opinion as to entering the Lotha Nága hills, that no Survey operations could for the present, be carried on in the tract in question, as the tribes were hostile.

(7.) I was in hopes however that it might have been possible to carry on a series, with alternate stations in the plains and in the outermost low range, which from the maps, appeared to lie in and along British boundary and were uninhabited, and I communicated with the District Officers on the subject and was informed, after considerable delay, that the Sibságar District had been closed to the Hill tribes and stockades erected to prevent their ingress into Assam; that no Survey party could enter into the Hill Districts without a very strong body of police, which could not then be furnished, and that the maps were quite untrustworthy, as the British boundary was at least 7 or 8 miles from the foot of the hills.

(8.) My plans for continuing the triangulation along the hills having thus been baffled in every way, I was compelled to resort to the plains and the triangulation was carried down on the side Kankochan H. S. to Cheníábúíshon H. S. With the hope of being able to obtain peaks on the outer range, the station of Golághát had been selected by Mr. O'Sullivan and a platform and pillar built. As the hills were no longer available, Mr. O'Sullivan was directed to carry the series by symmetrical, single triangles through the plains of Sibságar.

(9.) It was some time before I could decide on the most suitable course the series should take; proceeding in a direct line was inadmissable as the centre and southern portion of the District is studded with tea plantations and grants, the owners of which were not at all disposed to have lines run through their estates, or their property injured, even on payment of compensation, which was given in one instance last season, and was excessive in regard to the damage sustained. This was a consideration of the utmost importance as the means at the disposal of the party would not admit of such heavy compensation as would be demanded, while the progress of the work would probably be delayed by opposition and litigation. I therefore decided on carrying the series along the course of the river by which means very heavy jungle cutting, as well as tea plantations would be avoided and the height of the towers would be reduced, and there would be little or no compensation to be paid, thus making it the most economical course to adopt; at the same time the triangulation was not intended to be restricted to the river, but to deviate therefrom whenever it should be found necessary.

(10.) When the direction of the series had been decided upon I returned to the hills and visited Chenjábúshon II. S. and took the observations there, including those to Golághát T. S. and Bor-Chapri T. S. at the latter of which stations Mr. O'Sullivan had now built a masonry pillar. Observations at Chenjábúshon II. S. were completed on the 23rd February, at Bor-Chapri T. S. on the 26th and at Golághát T. S. by the 7th March. After this I took up the Approximate work until the beginning of April, returning to Kankochan II. S. to complete the observations to Bor-Chapri T. S.

(11.) The Approximate work during the past season has been carried only a very short distance owing to the lateness of the season, the nature of the country, the scarcity of local labor and the continued unfavorable weather. The out-turn of work is small but no energy has been spared, nor means untried to overcome the difficulties which had to be encountered and which are in my opinion greater than in any other part of India. The difficulties experienced in the selection of stations in the plains of Assam are manifold.

(12.) The country does not slope down gradually from the foot of the hills to the Brâhmáputra River, but consists of a succession of low ridges frequently covered with almost impenetrable jungle, not running parallel to the streams which generally flow down from the mountains at right angles to the river, as may be naturally supposed, but in most instances at right angles to those streams, with an abrupt fall into the basin of the Brâhmáputra. It is difficult in such undulating tracts with wide level bits of country, to fix upon any particular length of side, and it was found imperative to have the side Golághát T. S. to Madaigáon T. S. 10·4 miles, while the height of the tower at the latter place, it will be necessary to build over 30 feet to ensure mutual visibility. The series carried along the course of the river will render so great a height unnecessary for future stations.

(13.) Frequently extensive patches of tall grass and reed jungle were met with, which elephants were employed, by Mr. O'Sullivan, to crush down on the rays, by means of heavy logs dragged by them. In some places the rays have been carried through boggy and swampy ground with thick tall reeds which had to be cut one by one. Occasionally belts of jungle had to be traversed, the trees in which, with few exceptions, were of no great diameter, but were so interlaced with canes and bamboos, and had so heavy an undergrowth, that it was a most arduous and tedious undertaking to carry a narrow gap through. Between Bor-Chapri T. S. and Nikori Chapri T. S. Mr. O'Sullivan was occupied nearly three weeks in carrying a ray, the undergrowth on which was not only very heavy, but hid from view high mounds raised by earth-worms. In ground of this nature perambulators were useless and Mr. O'Sullivan adopted a rope 132 feet long made impervious to wet by means of wax and oil, and which was tested every morning.

(14.) Local labor was rarely procurable in Assam and the District Officers scarcely gave us any assistance whatever, although the villages occasionally met with were able to furnish a large number of coolies, and with proper parwánas the mauzádárs would have readily provided them. The difficulty of obtaining supplies for the camp was also a source of delay. These difficulties are however likely to be very much diminished next season, and with a better knowledge of the country and our requirements, an establishment now trained to plain's work, the progress in the ensuing season may be confidently expected to be more rapid and satisfactory.

(16.) The triangulation in the hills traversed the country of the Míkir and Ringmáh Nága Tribes whose characteristics have been already described by Mr Rossenrode, as well as the various insect annoyances, to which the party was also subjected during the last field season, though not to the same extent. No annoyance was experienced from tigers and wild elephants.

(17.) Very little Secondary work has been obtained, smoke and haze obscured the atmosphere from about the middle of January, and though occasional sharp showers cleared the air for a day or two, the distant peaks were invariably enveloped in haze and fog. Throughout the season, the weather has been very unfavorable, there had hardly been a week of uninterrupted dry weather, and at the beginning of April the rains were so heavy, that, in two days the plains were completely submerged.

(18.) The district of Sibságar in Upper Assam is one of the healthiest in the province and unless the rains are protracted, field work can be resumed early in November with safety. The atmosphere is generally very clear throughout that month and up to the middle of December, and I have hopes of being able to get a large amount of Secondary work early next season, soon after taking the field, which I purpose doing in the beginning of November. The health of the establishment was on the whole pretty fair. Four deaths occurred during the season, two of which were from complaints of long standing. The party arrived in recess quarters in the first week of May.

(19.) Mr. O'Sullivan accompained me from Gowhatty. Before taking the field he was employed in equipping and organizing the Native Establishment and in training men in the use of the heliotrope. As soon as Mr. O'Sullivan had fixed the station of Cheniábúíshon H. S. he descended into the plains and was employed on the Approximate Series. He selected 4 stations, built masonry pillars at two, carried about 55 miles of trial and 30 miles of final rays, and was compelled to close work on the 20th of April from want of supplies. Mr. O'Sullivan's progress, in spite of the great difficulties and hardships he had met with, is very good. His thorough knowledge of Assam and its people, his determination and energy, and zeal for his duties, combined with professional aptitude, render him the best fitted for conducting so difficult and troublesome an operation as the Approximate series in the Assam Valley.

(20.) Mr. Bryson accompanied me to Kankochan H. S. as observatory recorder and also took part in the principal observations at two or three stations. On Mr. O'Sullivan's taking up the Approximate work in the plains, he was at first employed to superintend the building of one station and to carry a ray from Golághát T. S. to Madaigáon T. S. Subsequently he was deputed to Secondary work chiefly with a view of fixing all the Revenue Survey paka pillars on either side of the Bráhmáputra River. Mr. Bryson from an utter want of energy and interest in his duties, has repeatedly failed to carry out my instructions, or to complete the work allotted to him.

(21.) Mr. Harris was transferred temporarily from the Bráhmáputra Series for the purpose of building the pillars required on the Eastern Frontier Series. He was much delayed by the unusual detention of the Assam steamer and joined the party on the 17th March. He took up the work assigned to him at once, and although new to the country and the language, was able to make his arrangements with his usual judgment and prudence. The continued heavy rain throughout the time he was engaged on his work threw him back considerably, and he could only complete two pillars and build the foundation of a third to a height of 1 foot, besides preparing materials &c., for a fourth station. Mr. Harris returned to recess quarters some time after the rest of the party, on the 28th May.

Extract from the Narrative Report—dated 15th July 1872—of Lieutenant M. W. ROGERS, R.E., Officiating Deputy Superintendent 3rd Grade, in charge Bombay Party.

(1.) The Head Quarters left Bangalore on the 6th November and marched to Gutti and thence by train to Ráichure, reaching the first station of the season, a few miles north of the river Kistna, on the 26th November. I at once commenced observations and continued them without intermission until the series was brought up to the sides Shilapali-Goraegat-Topkonda of Sir Andrew Waugh's Great Arc. This was completed on the 1st March.

(2.) The country, through which the series passed this season, belongs to H. H. the Nizám and is apparently little known or visited. About 20 miles north of the Kistna, a range of hills runs from east to west, parallel to the river, which is about 1200 feet above the sea;

on ascending this range the country is hilly and very stony in parts, and with a mean elevation of 1800 feet. There are no roads and the villages &c. seem to be generally in a state of decay, owing, I was told, to the failure of the rains for some years past. The greatest portion of the country traversed was Jágír-land, held by noblemen who reside in Haidarabad, and have apparently no care whatever for their dependents. In most of these Jágírs the Nizám's authority seems only nominal; the present Minister, Sir Salár Jáng, is however improving this state of things and is resuming all the Jágírs which were held for military service and are not family possessions. This has been done in several cases under my own notice, and the result to us has generally been—that where, under the Jágírdár, my assistant last year complained of hindrance and incivility, I have been agreeably surprised at the difference under the new *régime*. The new state railway runs across this tract of country and will probably bring roads and a better state of things in its wake.

(3.) The country to the west of the series is very stony; slate of a rough description is plentiful and is used in many places for roofing, and all the villages are built of a whitish stone which gives them a neat and clean appearance at a distance.

(4.) Towards Bider the whole country rises again and forms a second plateau, with an elevation of about 2000 feet. Along the southern portion it is covered with thick jungle, which, together with the flatness of the ground, caused considerable delay and trouble in effecting a junction with the old work which itself appears to have been carried out of the meridian in order to avoid that portion of the country. The soil about Bider is red, and ironstone abounds, and at Koyer and many other villages a good deal of iron is smelted; they do not, however, quarry very much, but use the ironstone gravel which seems very rich in metal.

(5.) On the completion of the Principal Series, I took up a Minor Series to fix the city of Haidarabad, and the cantonment of Sikandrabad. I used the 24-inch Theodolite in all cases save one, where I was obliged to choose a very rocky and difficult hill, in place of the hill of Golkonda, which I had reckoned upon occupying. At the instance of the Resident, my signaller was allowed to make a mark and shew his heliotrope from the fort, but when I arrived near the city myself, I was informed that no European was allowed into the fort or ever had been, so I was obliged to select a new point. Save the Chár Minár, a large building at the junction of the main streets, there are no prominent buildings in the city itself; the Mecca Masjid, though a well built handsome building, having no minarets of any size. This Series was finished on the 6th April. The next portion of the revision was 100 miles north and the weather had by this time become very hazy and hot, so I determined to march back to Gulbargah which I reached on the 14th.

(6.) I there placed the theodolite, tents &c. in safety and proceeded by train to Bangalor, which I reached on the 20th April.

(7.) The principal work of the field season has been as under;—

The series has been advanced 86 miles and completed. 56 angles have been observed at 16 Principal Stations forming the northern portion of a double polygon, one double polygon and the larger portion of a double polygon and compound figure, which forms the junction of the two series; the whole covers an area of 3099 square miles. An Azimuth was observed at Kodangal S., and 4 Zenith distance stations fixed around for Captain Herschel. 34 Secondary angles at 2 principal and 8 secondary stations were observed, on the Haidarabad Series, with the 24-inch Theodolite, covering an area of 832 square miles. (All Secondary and Intersected points, observed by the party, were fixed in height as well as position.)

(8.) Aneroid Barometer observations for height have been carried on regularly throughout this and the last field season whereby the heights of all the hills on which the stations are, and halting grounds, have been fixed. This season the heights of hills have been taken by simultaneous observations with two aneroids, a method of very fair accuracy. I have the honor to forward herewith a list of heights in the series from Bangalor to Bider and Haidarabad, containing two lines of road and numerous places in the districts. The heights from Bangalor to Gutti, were determined by simultaneous observations. Captain Herschel arranged to place his assistant and barometer at my disposal and I marched to Gutti, myself one stage in advance, whereby daily simultaneous differences were taken, the barometers being compared every evening. This arrangement when practicable should be very fairly correct. I shall be obliged, should this table of heights be printed, if a few copies of the table be printed separately and forwarded to me, as myself and Major Branfill often receive applications for heights in Mysor &c.

(9.) At the instance of the Resident, Mamsabdárs were appointed by H. H. the Nizám's Government to accompany the camp of myself and Mr. Price. The one for the latter gentleman did not appear, but to Mamsabdár Muhammad Faiyázuddín Khán and his sepoys who accompanied me I am much indebted; without their aid, I should inevitably have been delayed, and possibly have been brought into unpleasant collision with the employes of the Jágírdárs; as it was, I had very little trouble. My best thanks are due to the Resident and H. H. the Nizám's Minister for the help they rendered to me.

(10.) Mr. Price was employed in selecting and building stations on the Approximate Series; he selected 6 and built 13, besides selecting 8 Zenith distance stations for Captain Herschel. I have alluded to the difficulties of the junction figure, which necessitated a high perforated pillar station with a wooden platform for the observatory tent. Whilst selecting and building near Nander on the Sironj-Bider section of the Arc, his camp was attacked by small-pox and I am sorry to say he lost his wife; he himself suffered severely at the same time from fever, and I therefore directed him to rejoin me at Gulbargah whence he proceeded to Bangalor with the Head Quarters. As usual his work has been good and he has spared himself no exertion to carry it on; he is a very praiseworthy and able assistant. He has had the entire selection of the Series, and I trust that on the completion of his 9 years service he may be promoted.

(11.) Mr. Bond worked at and completed the Kadapa (Cuddapah) Minor Series, he triangulated a direct distance of 90 miles by 11 triangles covering an area of 1124 square miles, his instrument was a 10-inch Theodolite and his average triangular error 1·36 seconds. In addition he fixed 33 intersected points and closed all the stations of his initial sides. After finishing at Kaddapa he marched to Karnúl and began a short series to connect that place, but his health gave way under the exertion and great heat and he was ordered by the Surgeon of Karnúl to return to Bangalor. I have already communicated with you on the state of his health, which has been severely tried in the department. The quality of his work speaks for itself and I am entirely satisfied with it and that he has worked to the utmost of his power.

(12.) Mr. Torrens accompanied me as recorder for the first six weeks, during which time he instructed Mr. Oldham in his work; he then went with Mr. Price and selected and built a principal station, after this he prepared the Haidarabad Series; I then sent him to Captain Herschel under whose directions he marched north and selected 3 stations for Zenith distance observations and also reconnoitered the country with a view to choosing stations for doubling the Great Arc at that point. This year has been his first at any independent work and I see no reason to alter my favourable opinion of him. He has now served his time for promotion which I trust he will get when a vacancy occurs.

(13.) Mr. W. Oldham joined the department in October, from Bishop Cotton's School at Bangalor where he had been acting as under Master; he has been with me as recorder during the season and worked well and obtained all the necessary knowledge in departmental forms. At the end of the season he closed 3 stations independently and has altogether given me satisfaction.

(14.) During the last recess, one double Polygon, one Pentagon and one Azimuth were computed, together with all the Secondary work, bringing up the Series to date.

Heights in Mysor, Ballári (Belary,) Kadapa (Cuddapah) and the Nizám's Dominions.
** Bombay Party. Seasons 1869-70-71-72.*

Name of Place.	Aneroid Height.	Trigonometrical Height.	Remarks and Descriptions.
Bangalor		2989	Barometer Cistern in Civil Hospital.
Nellamangalam		2905	Ground level at Traveller's Bungalow.
Sompur		3050	Ditto ditto.
Tumkur		2681	Ditto ditto.
Rámádeverabetta H.S. ...		3883	Trigonometrical mark on hill near Tumkur.
Agraharam village ...	2530		By bridge over Surnamuky River South bank.
Maddagiri village		2462	Road outside gate on Sirah road.
Do. H. S. ...		3935	On corner tower of highest fort on drug.
Maddágaisi village ...		2452	On Paugarh road opposite Police thánah.
Do. Drug		3376	Highest point of hill.
Maddak Sira village ...		2173	On Paugarh road in tope beyond Town.
Do. Drug ...		2936	Col. Lambton's old station mark.
Raddam village	1902		In tope S. of village.
Pennakonda	1862		In tope outside walls close to Bangalor road.
Do. H.S.... ...		3091	On stone on the highest portion of fort.
Hindupur		2068	⊙ on Temple N. of Town.
Yerrakonda H.S.		2820	2 miles West of Gutti road at 69th milestone.
Innaglur H.S.		2900	Kadapa District. ⊙ on side of hill.
Mitiapalli village		1929	Village West of Innaglur, in tamarind tope.
Halsurbetta H.S.		3341	A little West of Gutti road at 16th milestone from Bangalor.
Do. village		2994	
Ambaji Drug H.S. ...		4339	⊙ on high hill 2¼ miles W. of Chintamanipet.
Do. village ...		2989	Tope N. of village at foot of hill.
Maukli Drug H.S. ...		3610	On road from Pedda Ballapur to Hindupur.
Do. camp ...		2562	At 11th milestone from Pedda Ballapur.
Suntapur village		2663	3½ miles N.N.W. of Doduirmanga.
Paugarh H.S.		3026	On Sultán's Battery in Drug.
Do. village		2062	On high road below the drug; outside village.
Chikápilli village ...	1848		14 miles from Paugarh on road to Ráidrug.
Kamakonda Drug... ...		3537	High hill ½ mile East of road.
Kumbadúr village ...	1781		18 miles from Paugarh on road.
Dasrampilli village ...	1807		27 ditto ditto ditto.
Kallián Drug H.S. ...		2383	⊙ on platform in fort, E. of village.
Do. village ...	1838		35 miles from Paugarh. Tope E. of village.
Davandelbetta H.S. ...	2395	2434	2 miles N. W. of Kallián village.
Urakonda H.S.		2193	½ mile East of Gutti-Bangalor Road at the 105th milestone; near Chinna Kotapilli village.
Kaunagaunpalli village ...	1384		17 miles from Chinna Kotapilli on the road from Darmaveram to Kallián Drug.
Kondapilli village ...	1582		Camp between Hill and Village.
Do. H.S.	2286	2259	
Halnúr village	1175		Camp S. of village.
Daverkonda H.S.	1824	1840	Near tank E. of Hundi Anantápur.
Do. camp... ...	1163		On side of tank E. of hill.
Kudligi village	1333		13 miles from Anantápur on Ballári Road.
Uderpi Drug village ...	1298		Camp S. of village on Ballári Road.
Do. H.S.... ...	1731	1725	
Zenith distance station ...		1570	2 miles S. W. of village.
Honúr H.S.		1583	1 mile N. E. of village on old Ballári Road.
Gaddakal village	1429		Camp N. of village in tamarind tope 22 miles from Ballári on the Gutti Road ⊙ General Cullen's height 1420.
Do. H.S.	1790	1823	
Aminapalli village ...	1270		Camp on road S. of tank.
Gundakul		1432	⊙ on roof of railway station. Genl. Cullen's 1500
Ballári Fort		1976	Base of Flagstaff in chief battery. ⊙
Do. Railway Station ...		1484	Railway levels.
Gutti	1238		Town; at cemetery foot of drug.
Do. Drug	2136	2101	Highest point.
Namthabad S.		1173	Trigonometrical station 3 miles S. of Gutti.
Kadrápilli village	1175		Camp ¾ miles N. of Nágásamudra village.

Heights in Mysor, Ballári, Kadapa and the Nizám's Dominions.
** Bombay Party. Seasons* 1869-70-71-72—(Continued.)

Name of Place.	Aneroid Height.	Trigonometrical Height.	Remarks and Descriptions.
Boglemaurkonda H.S. ...		2350	⊙ on top of hill.
Kondánúr village ...	1024		Camp in tope N. of village ½ mile W. of road.
Paumdi H.S. ...		1680	Flat topped hill close to Bangalor-Gutti Road.
Yainigamarri village	1634		¼ mile N. of village and E. of Karnúl-Gutti road.
Sudápalli village ...	1155		Camp by tank 2 miles E. of Karnúl road.
Kottúr village ...	1357		Camp E. of village.
Katomoraj H.S. ...	2052	2053	
Shitabanda village	1373		
Bandimaddagu village	1451		
Pulikonda H.S. ...	1811	1802	⊙ on solid tower 16 feet high.
Hospetta village ...	1321		
Gongondla village		1354	Highest point of low rocky hill.
Kerra Bellágal H.S.		1423	Hill S. E. of village of Kerra Bellágal.
Krishnadodi village	1055		Camp on bank of tank W. of village.
Adoni Drug H.S. ...	1997	2000	Trigonometrical ⊙
Malliabad H.S. ...		1771	Hill 4 miles S. of Ráichur. Nizám's country.
Do. village ...	1372		Camp on a knoll E. of village.
Darrur H.S. ...		1805	In Geddáwal Rája's territory.
Do. camp ...	1257		N. foot of hill ditto.
Nandinía village ...	1210		Camp in palmyra tope E. of village.
Kotápalli H.S. ...	1576	1579	4 miles N. of Kistna River.
Do. camp ...	1285		Half way between hill and village.
Chintalíkinta H.S.		1759	In Deodrug táluk 8 miles S. of the Kistna.
Do. village	1285		
Janíkalu H.S. ...		1555	In Manwi táluk 9 miles N. of the Tungábudra.
Do. camp ...	1292		Close to hill, opposite side to village.
Kinikerray village	1251		
Yedagiri village ...	1225		G. I. P. Railway Station is 1½ miles W.
Bima River ...	1164		Naikal Ferry. Water level in December.
Ditto ...	1189		Ditto on West bank.
Naikal H.S. ...	1610	1611	
Do. village ...	1207		
Yedagiri Drug ...		1792	Highest Tower.
Gannápur village ...	1328		¼ mile E. of village.
Naráinpet village ...	1454		Rája's garden N. of Town.
Muktul village ...		1295	Roof of highest house.
Inpálgat H.S. ...	2308	2340	
Do. camp ...	1758		½ mile S. of Trivallapur village.
Yeddalapuram village	1960		½ mile E. of village above the ghát.
Undurke village ...	1732		½ mile S. W. of village.
Korlah village ...	1565		½ mile S. of village.
Hudagi S. ...	1440	1438	Trigl. Station in field 1 mile N. of village.
Andaki ...	1445		Camp close to North of village.
Nellagat H.S. ...	2048	2036	
Rabbanpalli village	1892		Camp half way between hill and village.
Chittapalli village...	1862		In tope on road S. of village.
Kodangal S. ...	1907	1914	On rising ground 2 miles N. of village.
Kushgi ...	1706		Tope N. of Town on road from Kodangal.
Worval ...	1739		½ mile W. of large tank and N. of road.
Antawaram ...	1825		N. E. of village.
Pochamagat H.S.	2371	2358	
Kusmasamudram ...	2008		Close to village on S. side.
Tandúr ...	1508		East of village near tombs of Nizám's officers.
Gannápur H.S. ...	1584	1606	
Indúr village ...	1658		Close to West side.
Daravíd ...	1738		Tope E. of village.
Anantagiri H.S. ...	2311	2311	
Keravalli ...	1934		½ mile N. close to hill.
Koatpalli ...		1728	Foot of high Tower in village.
Mothakapalli H.S.	2284	2282	
Do. camp	1965		
Bachinapalli ...	2090		N. E. of village.

Heights in Mysor, Ballári, Kadapa and the Nizám's Dominions.
**Bombay Party. Seasons* 1869-70-71-72—(Continued.)

Name of Place.	Aneroid Height.	Trigonometrical Height.	Remarks and Descriptions.
Kandenmarrei T.S. ...	2227	2240	Lower mark, ground level.
Bihilpur	2162		Large tope 1 mile S. of village.
Womekonda H.S.... ...	2196	2178	
Do. camp... ...	1987		S. of hill.
Kúpánagar	2080		¼ mile E. of village on Bider Road.
Shilapali H.S.	2229	2199	
Pedda Chilmaira	2103		Tope E. of village and N. of road.
Goraegat H.S.	2052	2071	
Do. village	1963		Foot of hill, village side.
Topkonda H.S.	2185	2182	
Gazulgúda	2046		Camp N. of village.
Kothapalli	1973		By stream in tope E. of village.
Chebalilah H.S.	2201	2187	⊙ on low hill W. of temple.
Bakawaram	1799		In plantation E. of village.
Gaganpahár H.S.	1995	2016	
Do. camp	1814		In tope near road 6 miles from Haidarabad.
Husainsavalli Dargáh ...	1830		In tope, N. of road near Golkonda tombs.
Golkonda Fort		2024	⊙ on rock in fort.
Durgápahár H.S.		2089	On range of low hills N. of Golkonda.
Naubatpahár H.S. ...		1867	Small hill between Haidarabad and Sikandrabad.
Do. camp... ...	1719		S. End of Husain Ságar tank.
Mulkagiri H.S.		2007	Low hill 1½ miles N. E. of Lancer lines Sikandrabad.
Chár Mínár		1739	Balustrade; top of minaret about 65 feet higher.
Chaddarghát Ch.		1736	Basement of pinnacle.
Balárám		1977	Resident's flagstaff, lower cross piece.
Kishara H.S.		2089	
Do. camp	1786		N. of village halfway to hill.
Lechmápur H.S.		2115	
Nizámpet village	1930		Tope S. of village.
Sadulnagar	1724		In tope W. of road and S. E. of village.
Suldapur H.S.	2089	2088	
Umdanagar	1782		East of village.
Undol	1637		Tope S. of Town. General Cullen 1709.
Tadmanúr H.S.	1864	1851	

The High road from Bangalor viá Gutti-Adoni-Ráichur.

Bangalor		3131	Roof of observatory at S. E. end of Base-Line on Gutti road.
Davanhalli	2950	2956	Ground level of bungalow compound.
Chota Ballapur	3023		Ditto.
Patasamudram	2713		Ditto.
Gantwarpalli	2359		Varanda level.
Palsamudram		2237	Ground level.
Ponnakonda	1862		In tope near old dák bungalow.
Chinna Kotapilli	1433	1444	Bungalow compound.
(Darmaveram)		1201	Level of ground at old palace. (Old road.)
Marúr	1269		Bungalow compound. New road.
Hundi Anantapur ...	1156	1152	⊙ on *tehseeldar's house in town.
Garuldinni	1080		In tope close to old bungalow.
Yeggawopalli	1068		Road bridge parapet 15½ miles from Gutti.
Gutti	1220		¼ mile S. E. of railway station.
Jonagiri	1361		
Pattikonda	1548		Camp close to fort wall on N. side.
Adoni	1418		Camp in tope close to foot of drug. Genl. Cullen 1395.
Hulikanáva	1201		15 miles from Adoni.
Tongábudra	1046		On N. bank E. of road. Haidarabad State. Genl. Cullen's height of Madaveram on S. bank 1089.

Heights in Mysor, Ballári, Kadapa and the Nizám's Dominions.
**Bombay Party, Seasons* 1869-70-71-72—(Continued.)

Name of Place.	Aneroid Height.	Trigonometrical Height.	Remarks and Descriptions.
Ráichur	1326		In Rája's tope between rail and fort.
Kistna River	1116		South bank. General Cullen 1129.

The Road from Sikandrabad to Gulbargah.

Sikandrabad		1791	Cistern of Barometer in Meteorological observatory.
Pattancherru	1791		Bungalow compound. Genl. Cullen 2062. ? error
Kundi	1757		Ditto.
Sedáshipet	1757	1758	Ditto. Genl. Cullen 1825.
Kumkoal	2054		Ditto.
Burra Yekali	2035		Ditto.
Cherrakpilli	1980		Ditto.
Mungulghi	1943		Ditto.
Hominabad	2030		Ditto Road branches off from Sholapur road.
Kíni	1864		Ditto Close to Mulámari River.
Korkotah	1439		Ditto do. Binathora River.
Gulbargah	1456		Camp at 135th milestone.

Aneroid Levels taken in the train from Gulbargah to Gutti, compared with Madras Railway values, the latter being level of rail.

Name of place.	Aneroid Height.	Railway Height.	Remarks.
Gulbargah Station ...		1488	
Shábabad	1351	1306	
Yedagiri	1171	1194	
Kistna River	1104	1139	G.I.P. Level 1113. G. T. Survey height 1146.
Ditto	1044		Bed of river.
Chiksúgúr Station ...	1130	1171	
Ráichur	1281	1311	
Matmarri	1185	1206	
Tongábudra River ...	1050	1081	Bridge level.
Do. Station ...	1061		
Kusgi	1211	1236	
Adoni	1350	1364	
Nuncherlah	1550	1553	
Gundukal	1412	1411	Trigonometrical height of station roof 1432.
Gutti	1193	1203	

The Aneroid Heights of Trigonometrical points, though given for the sake of comparison, have not been used. Each Aneroid Height, (except in the railway heights) is a mean derived from two adjacent Trigonometrical Stations.

All these heights are derived from observations taken with two gold band Aneroid Barometers (by Cooke and sons) at 9-30 A.M. and 3-30 P.M.

The observations were corrected for instrumental errors and also for daily variation; this latter quantity being derived from the fixed Mercurial Barometers at Bangalor, Karnúl and Sikandrabad Meteorological Observatories.

E.g. To obtain the height of Kudligi village

Height of Uderpi Drug H.S.,	1725	Height of Daverkonda H.S.,	1840	
Observed difference of height	— 390	Observed difference of height	— 510	
1st result	1335	2nd result	1330	Mean height 1333

The railway heights were taken at all hours of the day and night, and hourly variations applied.

Extract from the Narrative Report—dated 15th July 1872—of Major B. R. BRANFILL, Deputy Superintendent 2nd Grade, in charge of the Madras Party.

(1.) The Madras Party under my charge had not entirely recovered from the previous unhealthy field season, when, the first burst of the N.E. monsoon being over and the computations complete, it was possible to take the field on the 1st November 1871, but bad weather detained us till the 10th of that month.

Recess Season ended 1st November 1871.

(2.) I may here mention that the computations of the previous field season's work shewed that the point Anaimudi (a high peak in the Anaimallei hills) was no less than 8,837 feet above the sea, 195 feet higher than Dodabetta in the Nilgiri hills, hitherto supposed to be the highest point in Southern India.

Reputed highest hill in Southern India.

(3.) My instructions were to leave the Southernmost Section of the Great Arc on which this party had been engaged for three or four seasons previously, and to take up the remaining triangulation of the Mangalur Longitudinal and Meridional Series, about 110 to 120 miles on each—probably two season's work.

Party quits the Great Arc (Revision) to complete the triangulation near Mangalur.

(4.) The Approximate Series of the whole was stated to be complete, with the exception of two stations about the point of junction near Mangalur; but only five stations in advance of the side Nughalli-Nárayan Drug (observed in 1867-68) were built. I was furnished with charts of the approximate series, and descriptions of the five stations built.

Entire Approximate Series already completed.

(5.) As soon as the weather permitted, on the 10th November, the party left Bangalor, and reached Nughalli on the 17th and 18th marching in two parties for the sake of observing a Barometric Leveling traverse, by means of corresponding simultaneous observations with two pairs of Aneroids—the result of which, notwithstanding the unfavorable state of the weather, proved highly satisfactory, the closing error being only about 7 feet. Barometric observations were also taken daily throughout the season at 10 A.M. and 4 P.M. by the main party, and by two of the assistants detached.

(6.) At the commencement of the field season I made the following disposition of the party.

I myself remained with the main or observing party to take the Principal observations until Lieutenant McCullagh should become sufficiently practised with the 24-Inch Theodolite to conduct the work alone. I then purposed examining the Approximate Series in advance, and after that to set up the self-registering Tide-Gauge at Mangalur, which had been named as a Tidal station, leaving Lieutenant McCullagh to complete the final observations with the 24-Inch Theodolite.

Disposition of party.

Mr. Mitchell was directed to complete the Ammedikal polygon, of which two stations remained for selection, and then, in accordance with my instructions to select and observe a series of triangles extending along the coast south of Mangalur as far Ponnáni in latitude 10° 48′.

Mr. Norris, whose health was still bad and unable to bear the trying weather we now experienced, viz., cold wet nights with strong dry and hot N. E. winds by day, I directed to take up the station building in the low country to the west of the Ghâts, and afterwards to assist me at Mangalur, whilst Mr. Potter was sent to build the stations above the Ghâts and northward up the Meridional (Approximate) Series, and Mr. Laseron remained as Office assistant and Observatory recorder with the main party.

(7.) At Nughalli II. S. I observed an Azimuth to δ Ursæ Minoris at Western Elongation; and 51 (Hev.) Cephei at Eastern Elongation; which, owing to rainy and cloudy weather caused a delay of four days. The result of the observations shews the computed Azimuth as brought down from the Calcutta Base to be 3″·774 too great, or the observed Azimuth in defect 3″·77 ½, the difference being in the same direction as, but greater in amount than that previously obtained on this Series.

An Azimuth observed at Nughalli II.S.

(8.) A further delay of several days occurred, by the signal party sent to occupy the great Pushpagiri II.S. (the "Soobramunny Hill" of Atlas Sheet No. 43) being misled, and attempting to ascend from its inaccessible side.

Delays.

(9.) But a more serious delay was met with at Sátanhalli H.S. the central station of the first polygon, where, after some days fruitless efforts to obtain a signal from Dásáni H.S., the N. flank station, the ray proved impracticable, being obstructed by a large portion of the top of an intervening hill. I selected a new point on the Dásáni group of hills, fortunately without much difficulty, leaving Lieutenant McCullagh, who by this time was quite able to carry on the observations alone, to measure the new angles; but this failure of the Approximate Series cost us no less than 10 days of the best weather for observing.

Failure of Approximate Series.

(11.) The principal observations were carried on without further hindrance than that caused by the forests and mountainous country of the Malnád and Western Ghâts, in which clouds and heavy mists frequently obscured the signals, and the distances traversed between each station were very great, occupying eight days on the average, and as many as eleven and twelve days in two cases.

Difficult country.

(12.) About the end of January whilst observing at Pushpagiri H. S., Mr. Potter reported that the Approximate Series had again failed in Kudurei-Mukh H. S., the first point common to the Longitudinal and Meridional Series, and that his station building was at a standstill until he should receive fresh instructions how to proceed. These I sent him immediately but owing to the great distances, nearly three weeks elapsed before he could resume his duties.

2nd failure of the old Approximate Series.

(14.) In view of the somewhat small and ill-conditioned figures provided, and thinking that the number of the stations must be reduced to ensure the completion of this triangulation next season, I determined to remodel the series in advance, by throwing back (eastward) the side of junction and selecting a figure to the North-East of Kudurei-Mukh above the Ghâts, that should as it were, "cut off the corner," leaving Mangalur to be fixed by an independent quadrilateral figure, which (latter) however had to be abandoned during the observations for two single triangles, the greater diagonal being too long for observation at that season of the year. The country being rugged and roadless, I proceeded on foot from Kudurei-Mukh to examine it to the N. E., and succeeded, with Mr. Potter's assistance, in selecting three new points of a figure by which I hope the series will be improved and abridged, and rendered capable of completion next season.

Mr. McGill's plan of Series abandoned, and Approximate Series recast.

(15.) As the season was now (at the end of February) far advanced I suspended the Approximate Series work, and, having directed Mr. Potter to build the remaining stations, and to close and deliver to the civil authorities those visited and finally observed at this season, I proceeded to Mangalur for the Tidal operations, after satisfying myself regarding the connection of Mangalur pillar station with the main Series.

Approximate Series operations ended.

(16.) Meanwhile and till the end of the season, Lieutenant McCullagh with the main party had been greatly impeded in his observations with the 24-inch theodolite by the hazy weather setting in. At Ballamallei, the south-westernmost flank station, he was detained 15 days, at Ammedikal (central station) 18 days, and at Kudurei-Mukh 25 days, until the 10th May, when, as there was no hope of completing the observations before the beginning of the monsoon, he closed the season's observing and marched to Bangalor, where the party arrived on the 28th May, having suffered much latterly from fever.

Principal observing hindered and finally stopped by bad weather.

(17.) I had instructions to set up one of the new self registering Tide-Gauges by Adie London, at Mangalur, which I accordingly proceeded to do. I found the river (Netravati) which runs northward past the town of Mangalur, separated from the open sea for several miles, by a spit of sand varying in width from 100 to 400 yards, and 10 or 12 feet above sea level in the highest parts. I learnt that this spit had been extending northwards steadily for many years, driving the river mouth and bar continually before it. The older parts of the sand spit were covered with a growth of sea pink and many other plants, and were apparently very firm and not liable to shift. Some years since, a breach was cut in the spit to allow the river to enter the sea a mile or so short of its mouth at that time, and rather above (south of) the town: but a very few tides sufficed to fill up the gap, of which now there is scarcely a trace to be found. From this and other local information, there seemed good reason to suppose that the sand spit might be considered more than sufficiently permanent for a year's tidal operations.

Tidal operations at Mangalur.

(18.) As I could hear of no better place on the coast nearer than Kárwár (or Sadáshighar) which is beyond the limits of the triangulation remaining to be done, I determined to make the attempt to establish a Tidal observatory here, although there was some room to doubt of success; and accordingly I sank a masonry well in the highest part or ridge of the sand spit, where it was 12 feet above sea level and 30 yards away from high water mark on the beach, about a mile south of the river mouth, and nearly opposite the town of Mangalur.

A Tidal observatory decided on and begun, and a masonry well sunk.

(19.) The sand was very firm at a small depth below the surface where it was slightly moist, but exceedingly "quick" at the permanent water level below, which I saw reason to believe to be considerably higher than mean sea level. The well was begun a little above this, and sunk by emptying the sand continually from its bottom, and adding to its height, until there was always a depth of 6 feet of water or more in it, and 10 feet of masonry above high water mark.

(20.) Communication with the open sea was now established by means of wrought iron gas piping, of one inch bore, with a copper perforated nozzle, extending 40 or 50 feet beyond extreme low water mark of spring tides into 4 or 5 feet of water, the other end being introduced into the well at about the mean level of the sea, which was the lowest that could be managed even at low water, owing to the wash of the waves and the persistent high level of the water standing in the sand spit. A syphon end extending to the bottom of the well having been added to the inner end of the pipe, it was found that although the communication with the sea was apparently free enough about high water, at low water the pipe was inadequate to empty the well more rapidly than it filled by percolation from the sand below. It was necessary therefore to introduce a watertight case or cistern that should only admit or deliver the sea water by means of the pipe. This proved an exceedingly difficult task, more especially so as the season of perpetual rollers from the South-Westward and a heavy surf on the coast had set in by this time, (the beginning of April) and prevented the removal of the pipe in order to let down the case entire.

Communication with open sea established.

(21.) After one or two trials I succeeded in securing a water-tight case of wood (10) ten feet in depth in the required position with the pipe standing. This occupied the time till the end of April, and the result appeared to be satisfactory, but being near the time of neap tides the range of the tide was too small to test the efficiency of the arrangement thoroughly, when, rather suddenly, the free communication with the sea ceased; the water having shoaled and covered the sea end of the pipe with about a foot of sand.

A watertight cistern or case of wood introduced.

I found that water would still flow out of the cistern freely, but that even with a considerable head of water outside it would scarcely flow in at all.

The pipe choked by deposit of sand.

(22.) By this time a masonry platform with deep foundations had been built to support the iron bedplate of the self-registering Tide-Gauge to be set up, a small thatched hut or observatory erected, and the instrument wth clock put in position ready to start.

Masonry platform completed and self-registering Tide-Gauge set up.

(23.) The severe gale of wind from the W to N. W. doubtless connected with the devastating storm which occurred at Madras about the same time (1st and 2nd May,) now took place and considerably altered the shore line, washing away much of the sandspit almost up to the observatory and well, and shoaling the water for some distance out to sea.

Damage by severe gale of 1st and 2nd May 1872.

(24.) The season of high surf was now too far advanced to do anything further, and notwithstanding the statement that the alteration of shore line and sea bed was very unusual, it seemed best to pack away the instrument safely and defer further operations till the close of the monsoon.

Tidal operations closed.

(25.) I regret to add that the unusual violence of the monsoon has made further encroachments, and the Executive Engineer to make sure of saving the materials from being lost has removed the observatory hut, but not before much damage and loss had occurred from the violence of the waves.

Further damage and removal of observatory hut.

(26.) To set up a Tidal observatory and maintain it in operation for a twelvemonth on the sandy shore of an open coast, like that of the Indian Peninsula, is an affair of such difficulty and

Considerations against success at Mangalur.

expense, and at best so uncertain of success, that it can hardly be recommended; and I greatly fear that Mangalur must be abandoned as a Tidal Station, and a protected spot sought for. If the pipe of communication with the sea be made long enough to be beyond the line of surf and shifting bottom, the bore must probably be enlarged beyond a practicable limit, to ensure rapidity of action; and I doubt if any manageable length of tube will secure it from the liability to be buried or shifted on the sandy shore of the Western Coast.

Reason for success at Tutukudi (Tutikorin.)

(27.) I attribute the success of the Tuticorin Tidal operations just completed, (see para 37) to the protection of the harbour and the fact that the end of the tube could always be got at and examined.

Permanent Bench-marks fixed and levels determined.

(28.) During the progress of the Tidal observatory, three new permanent stone Bench-marks were marked in the usual manner and connected by Spirit leveling with each other and with Captain Basevi's points leveled in December 1869, (the results agreeing well with his), and a double line of levels was carried by Mr. Norris to the new G. T. Survey pillar Station at the Lighthouse recently built and observed at, about a mile or more distant.

Return to Bangalore.

(29.) On the 7th May I left the instruments &c. in charge of the Executive Engineer at Mangalur and proceeded to Bangalor where I arrived on the 1st June.

Brief statement of Season's work.

(30.) The following is a brief statement of the field season's work :—(15) Fifteen Principal Stations were visited and (40) forty angles observed, fixing (10) ten new principal stations, by (11) eleven triangles embracing an area of 3239 square miles, executed at a cost of Rs. 14 per square mile, and extending the Series above (100) one hundred miles from East to West across the mountain range of the Western Ghâts, besides a good proportion of Secondary and incidental work ; 55 Secondary points fixed, spread over 2053 square miles beyond the principal triangulation; also a year's series of Tidal curves secured, with hourly readings made and tabulated. Also a connection made by Spirit leveling between the closing station of the Series at Mangalur and several Tidal Bench-marks.

(31.) I trust that you will endorse my belief that the amount of work done and progress made, has been satisfactory in spite of unusual hindrances.

Lieutenant J. R. McCullagh, R. E., Assistant Superintendent 1st Grade.

(32.) I beg to point out to you that a large share of the Principal observations was done by Lieutenant McCullagh alone, and that although this is his first season's practice, with the 24-Inch Theodolite, the results, tested by the computed errors, weights, and corrections, appear to be very good, and compare very well with the results of other observers in the Department. Thus the mean triangular error, usually large (about 0".5) with the theodolite in use with this party (No. 1 Troughton and Simms-altered) is only 0".33, whilst the mean probable error of the (40) forty angles is only ± 0".14, the mean of the 7 previous seasons being ± 0".18. I consider these good results are due in a great measure to Lieutenant McCullagh's extreme care and aptitude for the work. This officer was attached to this (the Madras) party in October, just before taking the field, in a bad state of health from which he recovered but slowly : during November, December and January he took a large share of the office and observatory work, the details of which he soon mastered, and from 1st February he had sole charge of the main or observing party which he conducted to my satisfaction to the end of the Field season.

I am greatly obliged to Lieutenant McCullagh for the very willing and able manner in which he carried out my wishes, and I have much pleasure in stating that I consider him in every way fit for the sole charge of a Trigonometrical party.

Mr. J. W. Mitchell, Assistant Surveyor 1st Grade.

(33.) Mr. Mitchell's outturn of work is as follows:—Two Principal stations selected and eleven Minor Series stations, forming a single Series of eleven triangles, extending about one hundred and twenty miles along the coast to the South of Mangalur and bridging the gap left at this place in the chart of Colonel Lambton's triangulation. He observed the angles at five of the southernmost stations. The mean error of the two triangles observed is 7".3. So large an error must be attributed to the extremely unfavorable state of the weather during the observations. Mr. Mitchell also finally closed one Principal station and kept up a series of Barometric observations throughout the season, and only reached Bangalor on the 8th June suffering much from sickness.

Mr. O. V. Norris, Asst. Surveyor 3rd Grade.

(34.) Mr. Norris has built three Principal stations with ordinary platforms, one masonry pillar (11¼ feet high), two wooden observatory platforms (10 and 12 feet high), cleared some two miles of rays, executed one or two miles of Leveling, and finally closed two of the Principal stations. Mr. Norris was ill when he took the field, and frequently suffered from fever. It was on this account that I sent him at once to the low country near the sea, in the hope that his health would improve, and I believe it did so, but he was very frequently unfit for work and unable to bear much exposure in the forenoon and middle of the day.

Mr. C. D. Potter, Asst. Surveyor 3rd Grade.

(35). Mr. Potter has done a good season's work in spite of unusual difficulties. He has built, and well built, seven platform stations all on the top of high hills or mountains, finally closed five, and has selected one principal and six secondary stations, clearing and making 12 miles of pathway. Nearly all his work being in the mountainous country of the Western Ghâts and Malnâd of Mysor, labor and materials were only procurable with much difficulty and delay. Mr. Potter took a series of Barometric observations throughout the season, and his weekly diaries, reports with sketch-charts, observations and monthly papers were always well done, and sent in with regularity and in a workmanlike style. He and his party suffered very severely from fever in the Field. I have much reason to be pleased with Mr. Potter's conduct and beg to bring his name to your notice for favorable consideration.

Mr. E.W. Laseron, Assistant Surveyor 4th Grade.

(36). Mr. Laseron as Office assistant and Observatory recorder has worked well, and I have every reason to be satisfied with him. The angle books, field computations, and office records, have been duly kept up with neatness and regularity. Mr. Laseron's capacity, attainments and willingness are greater than the mere performance of his duty requires, and his conduct is as already often reported, unexceptionable. He has served well for more than three years in the Department and I therefore beg to recommend him for promotion on the first opportunity occurring.

The Tutukudi Tidal Observations completed.

(37). In addition to the Trigonometrical work detailed above, I have to report the completion of a year's Tidal Observations at Tutukudi.

In May 1871, I set up a self-registering Tide-Gauge (No. 1 by Adie, London), checked its performance by means of a temporary Gauge and connected it with the permanent Bench-marks previously provided for the purpose.

Captain G. A. Phipps, Master Attendant for the port of Tutukudi most kindly undertook the duties of tidal observer, daily dating the curves traced, winding the clock weekly and keeping it right, and, changing the sheet of paper on the drum every fortnight, whilst the services of a native writer were retained for the daily register of anemometer, barometer, and thermometer readings, and a copy of the meteorological notes made in the Master Attendant's office. The level of the instrument was re-tested in November 1871, and again at the end of the year's work in June 1872 when Lieutenant McCullagh was deputed to examine, test, dismantle and pack up the instrument. This duty he carried out to my entire satisfaction, thus closing what I trust will prove a most valuable and accurate register of the sea level. I have taken hourly readings of the registered curves, as well as readings of every high and low tide through the entire period. A special report will be sent in as soon as the preliminary reductions have been made and tabulated, but I take this opportunity to express my great obligations to Captain Phipps for his uniformly ready assistance, and for his constant attention so freely accorded.

Extract from the Narrative Report—dated 29th August 1872—of Captain W. J. Heaviside, R. E. Officiating Deputy Superintendent 3rd Grade, in charge No. 4 Extra Party.

(1.) The Party reached Head Quarters, Dehra Dun, from Tibet on the 19th of September 1871. Mr. J. B. N. Hennessey, Deputy Superintendent 1st Grade, was then in charge.

(2.) For some six weeks after the arrival of the party in Dehra, Mr. Hennessey, with Mr. Macdougall's assistance, was occupied in arranging the affairs, and sorting the papers of the late Captain Basevi. This was no light task.

Owing to the sudden nature of Captain Basevis' death, in a place where the facilities for carriage were most limited, and where he had none of the conveniences afforded by an office; it was but to be expected that his private and professional papers would not be sorted. Moreover, he alone, in India, was thoroughly conversant with the pendulum operations: and the computations for the last stations at which he observed had not been completed. It was, therefore, most essential that every record which could throw any light on the smallest detail of his delicate and valuable operations should be preserved: not only as a guide for his successor, but, also, that none of the hard earned results connected with his memory, should be lost to posterity. With this end in view Major G. H. Basevi kindly permitted all the properties, both public and private, which Captain Basevi had with him at the time of his death, to be brought to Dehra intact. There were also other books, papers &c., which had been left at Dehra. These were all carefully gone through by Mr. Hennessey who was thus enabled to collect all records and notes which Captain Basevi had preserved in the course of the operations from 1865.

(3.) After the papers had been sorted, the instruments were examined. The knife edges of the Pendulums were well oiled, and the whole apparatus carefully packed away.

(4.) Mr. Macdougall then took up the reduction of some of the pendulum observations. He afterwards assisted in the Computing Office for about 2 months.

(5.) At the time of Captain Basevi's death I was in England on furlough. Being offered the charge of the party, with a view to completing the pendulum operations, I left England and arrived in Dehra on the 11th of April.

(6.) I took over charge of the party from Mr. Hennessey and on the 20th of April the party moved up to Masúri.

(7.) The pendulum observatory at Masúri had been recently used for base-line bar comparisons. The removal of frame-works and pillars from the observatory, as also filling up the pits into which the bars had been lowered, occupied some days. During this time the vacuum cylinder was opened out, cleaned, painted, and made as air tight as possible. It was then found that the frame-work and arrangement of the apparatus, as used in the plains of India, had been somewhat modified by Captain Basevi to meet his requirements in the high table lands of Tibet. A certain amount of reconstruction was therefore necessary. Captain Basevi has left a detailed account of the methods he employed in observing, and, also, drawings of the different parts of the apparatus. But there are many little details connected with the work which are only to be learnt by experience. For instance, the large air pump was not taken to Tibet and had lain by some time; it required thorough cleaning, when put together and set to work it was some days before the proper size of the piston wads: the right length of the stroke: and the correct adjustment of the values was hit upon, so as to reduce the pressure in the cylinder below one Inch. There were similar delays with other parts of the apparatus and eventually the rains commenced before every thing had been got into thorough working adjustment.

So long as the fine nights lasted, I occupied myself in comparing clocks and chronometers, and in taking transits of stars.

(8.) During the recess, I have been engaged in arranging my predecessor's papers under headings; and in becoming acquainted with the methods he followed in observing and in computing out his results. I have also practised clock comparisons, observing coincidences with the pendulums, and other details connected with the work. I think I have now attained sufficient knowledge of the operations, to enable me to commence a regular set of observations at Masúri, so soon as the rains cease.

(9.) Mr. Macdougall has been chiefly employed during the recess in making duplicates of the Pendulum computations. He has afforded me assistance by his knowledge of the forms of computation and of the places in Captain Basevi's books, where tables &c., are to be found.

(10.) I am greatly indebted to Mr. Hennessey for the cordial assistance, and for the many useful hints he has given me in the course of my work. Mr. Hennessey was associated with Captain Basevi, in determining many important matters connected with the Pendulum experiments, and his knowledge has, therefore, been to me invaluable.

Extract from the Narrative Report—dated 15th August 1872—of H. KEELAN, ESQ., Officiating Deputy Superintendent 2nd Grade, in charge Bilaspur Meridional Series.

(2.) The party left Chanár (Chunar) on the 19th of November to resume the operations on the Biláspur Series; and arrived at the Tower Station of Pathaidi on the 17th December, where it was required to observe the verificatory Azimuth, which could not be obtained at the close of the operations of 1870-71, owing to unfavorable weather.

(3.) On the following day the 18th the thatch roofing was removed, and the tower found in excellent preservation. On the 20th the observations to δ Ursæ Minoris were begun, and finished on the 26th of December.

(4.) Immediately on my arrival at Pathaidi station, I instructed Mr. Surveyor L. H. Clarke to proceed without delay to the stations of the pentagon formed round the station of Charkádi, to clear all the rays and commence the preparation of materials for the construction of the towers of the figure, during the absence of, and whilst I retained the services of Mr. H. E. T. Keelan to assist in the star observations at Pathaidi, in consequence of the inexperience of Mr. Probationary Assistant Surveyor H. Healy in observatory duties: he having recently joined the department.

(5.) On the completion of the Azimuthal Observations, I instructed Mr. Surveyor H. E. T. Keelan to relieve Mr. L. H. Clarke of the work entrusted to him; whilst I proceeded myself, to the stations on the eastern flank of the series to build the platforms and cut the roads to them: Mr. Clarke meanwhile, was ordered to clear the rays and prepare materials for the tower stations forming the two quadrilaterals with the hill points.

(6.) After finishing the platforms at the hill stations of Silighát, Chapora and Khalári, I retraced my steps northward to begin the final observations; but, owing to numberless difficulties to be surmounted, the towers of the Charkádi pentagon were not ready before the 20th of February, when observations were commenced; and by the end of the month were completed at the tower stations of Bardha, Latúa, and Gúma.

(7.) During the month of March, final observations were completed at the tower stations of Charkádi and Jerwa, at the hill station of Silighát, and a few zeros at the hill station of Chapora.

(8.) During the month of April, final observations were completed at the hill stations of Chapora and Khalári, and the tower stations of Achola and Mahásamand; after which, I proceeded to erect the rectangular pillars, and transfer the care of the hill station platforms of Silighát, Chapora and Khalári, to the village officials. I then erected a substantial thatching over the tower of Mahásamand, and marched with the camp to Jabalpur to recess the establishment.

(9.) The season's final work consists of one pentagon and two quadrilaterals. The Approximate Series, extending about 60 miles from the North, on the base Mahásamand to Khalári, consists of 4 quadrilaterals, and completes the junction with the triangulation brought up from the South, on the base Pendra H.S. to Deopahár H.S. of the Biláspur Series. And lastly, the Minor Triangulation to determine the position of the Civil Station of Ráipur.

(10.) In the prosecution of the season's work, it was found, that owing to the character of the Chattísgarh district, through which the Biláspur Series passes, being of a wild nature, there existed no buildings or temples or other permanent objects to fix. The inhabitants, who are chiefly aborigines are content to dwell in huts huddled together, in smaller or larger groups bearing a name. Occasionally may be seen a demolished Budhist temple in the depths of a dense forest, on sites where in some remote period existed a large brick, or stone built town; so that there are no objects in the country to observe to, and therefore, no secondary points were determined from the principal stations of the series, except one building, the large modern temple of Bandhár—erected recently by a sect who emigrated from the north into these provinces about a hundred or more years ago. On this account, I detached Mr. Surveyor H. E. T. Keelan into the more open part of the district to the westward, to determine the position of the Civil Station of Ráipur, as well as to fix as many buildings, temples, &c., as he could manage to see along the course of the Minor Triangulation. But even here, the country was quite devoid of buildings.

(11.) Mr. Surveyor L. H. Clarke was, as already mentioned, detached from the station of Pathaidi with instructions to clear the rays and prepare materials for towers of the Charkádi pentagon; when on the 30th of December he was relieved by Mr. Surveyor H. E. T. Keelan, and ordered to proceed upon similar work connected with the stations of the 2 following quadrilaterals, all of which he did satisfactorily; and by the 20th of February completed the towers of Achola and Mahásamand, when he received fresh orders to proceed without delay and extend the Approximate Series southward, on the base Mahásamand T.S. to Khalári H.S., as directed in the following extract of my letter of instructions to him on the subject, dated 22nd February 1872.

"The series will be composed of polygons; and it will be advisable to select at "least two figures in advance in the direction of the parallel lines indicated in the plan fur- "nished you; so as to form a satisfactory junction, if practicable, during the present season, "with the approximate series now being carried up by Mr. Surveyor H. Beverley from the "south, and with whom you must put yourself in communication and exchange plans of figures "selected from north and south."

(12.) Mr. Clarke lost no time in this undertaking, and I was glad to find that by the end of March he had formed the desired junction upon the base Pendra H.S. and Deopahár H.S. by means of 4 quadrilaterals. On the whole Mr. Clarke has done a good season's work; and I deem it necessary to bring the same to your favorable notice.

(13.) Mr. Surveyor H. E. T. Keelan was first of all employed in assisting at the circumpolar star observations at Pathaidi Tower Station, on the completion of which, I directed him to relieve Mr. Surveyor L. H. Clarke of the duties on the Charkádi polygon; and notwithstanding the great difficulties he had to encounter, especially in the supply of water to build the towers, which, in most cases, had to be carried to the spot from long distances, he completed all his towers by the 20th February. I next instructed him to extend a Minor Triangulation to fix the position of the Civil Station of Ráipur, upon the base Achola T.S. to Mahásamand T.S., which he completed by the 12th of April, and joined my camp on its march up to Jabalpur shortly after.

(14.) Mr. Assistant Surveyor H. Healy, who joined this party on his appointment to the Survey in October, was daily instructed in the use of the small theodolite on the march from Chanár to the Central Provinces, and was subsequently sent under Mr. Clarke's orders to be instructed in ray tracing and clearing, until his services were wanted in the observatory. This young assistant I am glad to state readily became familiar with the work required to be done in the observatory and office, and promises in due time to become a useful hand.

(15.) The following computations appertaining to the Biláspur Series operations were completed during the recess of 1871.

I. The duplicate copies of Principal and Secondary Horizontal and Vertical Angles completed—means and angles deduced and compared with their originals.
II. Computations of 36 weights of angles, in duplicate.
III. Polygonal computations of the Gathaora and Pathaidi hexagons, in duplicate.
IV. Computations of 14 Principal Triangles in the above polygons, in duplicate.
V. Computations of Latitudes, Longitudes and Azimuths of 10 Principal Stations, in duplicate.
VI. Computations of Heights of 10 Principal stations, in duplicate.
VII. Computations of 10 Secondary Triangles, Latitudes, Longitudes, Azimuths and Heights of the Biláspur, Ratanpur and Bisrámpur Minor Triangulation, in duplicate.
VIII. Preliminary Chart for season 1870-71, on the scale of 1 Inch=4 Miles, with numerical data inserted thereon.

(17.) During the past field season a great deal of malarious fever prevailed amongst the men of the Establishment; and the Assistants, as well as myself were not exempt from it. The country is of a wild character; and it is more so southward.

(18.) The total expenditure during the official year 1871-72 is Rupees 40,333-10-9. The total area triangulated is 645 square miles, and the average cost per square mile is Rs. 62-8-11.

Extract from the Narrative Report—dated 30th August 1872—of Captain T. T. CARTER, R. E., Deputy Superintendent 2nd Grade, in charge No. 3 Extra Party.

(1.) On the retirement of Mr. C. Lane, Deputy Superintendent 2nd Grade G. T. Survey, on the 3rd of October 1871, and pending the arrival of an officer of the Senior Department, the charge of the party was held by Mr. A. W. Donnelly, Surveyer 2nd Grade G. T. Survey, and under his orders the party left their recess quarters at *Benares on the 8th of November, with the view to commencing operations at the G. T. Survey Bench-mark at Parsoni, embedded $\frac{3}{5}$ of a mile from the village of Parsurman, on the road (under construction) from Muzaffarpur to Purniah, the terminal point of last season's work.

(2.) On taking the field, Narsing Dás Native Surveyor was in charge of No. 2 Level, pending the arrival of an officer to the permanent charge of the party.

Superintendent's instructions.

(3.) The programme of operation as laid down by the Superintendent in his letter No. $\frac{16}{1362}$ dated the 27th of October 1871 was as follows: From the $\frac{\text{G. T. S.}}{\text{B. M.}}$ embedded at Parsoni near the village of Parsurman to continue the line of levels viâ Sáhibganj (Náthpur) to Purniah, connecting with the Great Trigonometrical Survey tower stations of Rámnagar and Dighi and such others as might be conveniently near the main line of levels. From Purniah to carry the line down to Karágola ghát, cross the *Ganges river and effect a junction at the G. T. Survey Bench-mark at the Pirpanti Railway station E. I. Railway, thereby completing the circuit from Gorakhpur to Pirpanti. After this to commence a fresh circuit from Purniah, and after connecting with the base-line stations of the Sonákhoda base, to continue the operations down the road from Titalia to Dinájpur, connecting with the stations of the *Calcutta Meridonial Series.

Commencement of work.

(4.) Mr. Donnelly arrived at Parsurman on the 11th of December, and after the customary tests had been made to ascertain the stability of the Bench-mark embedded at the close of the previous season's work, and after the level staves were compared with the portable Iron standard bar and the collimation of the levels themselves examined under Mr. Donnelly's directions, work was commenced on the 13th of December from the Great Trigonometrical Survey Bench-mark at Parsoni.

Captain Carter takes charge.

(5.) I arrived at *Bombay on the 16th of December from one year's leave to England on private affairs, and there found instructions to proceed to Purniah and take over charge of the party; arriving at Purniah on the 25th of December, I placed myself in communication with Mr. Donnelly with the view to ascertaining the point up to which the operations had been carried, and what progress the work had made; on receiving his reply I was enabled to join his camp and took over charge from him on the 8th of January 1872.

Progress of the work under Mr. Donnelly's supervision.

(6.) From the 13th of December to the 8th of January Mr. Donnelly had completed 64 miles of double leveling. Starting from Parsoni G. T. Survey Bench-mark the main line had been carried to Singesar Thán, from which point a branch line was taken to fix a permanent mark in the small civil station of Madahpur. From Singesar Thán a branch line was also carried to the Kotgánwah Factory at which point it broke into two lines, one proceeding south; connecting the tower station of Dighi. Another north connecting the tower station of Rámnagar; returning to Singesar Thán the main line was continued in the direction of Náthpur, as far as Latona village connecting with the tower station of Latona. From Latona village the leveling for the rest of the season was carried on by myself using No. 2 level (hitherto used by Narsing Dás) and Mr. Donnelly using No. 3 level; the Native Surveyor whose leveling had been very satisfactory, returning to his ordinary duties of recorder.

Leveling across country.

(7.) From Singesar Thán the main line of levels were carried across country following a cart track, chiefly through high grass, as far as the village of Dewánganj on the road between Sapol and Pratábganj, during this portion of work the progress was considerably delayed owing to its being impossible to take observations at long distances in consequence of the refracted state of the atmosphere due to the high grass through which the levels were taken.

(8.) From Dewánganj the line was (after connecting the tower station of Dewánganj) carried along the road to Pratábganj and thence to Sáhibganj on the left bank of the Kosi river, the river being crossed at this point, thence continuing along the road to Purniah, connecting *en-route* with the tower station of Ghiba of the N. E. Longitudinal Series.

Paka points fixed at Purniah.

(9.) At the request of the Collector of Purniah a number of paka points were fixed in the vicinity of the station to serve as checks on proposed leveling operations to be carried out by the municipal authorities, connected with the draining of the station; values above sea level and a chart shewing their position were made over to the civil authorities.

(10.) Proceeding from Purniah the main line was continued along the road to Karágola ghát at which point the river Ganges was crossed, thence viâ the village of Pírpanti to the G. T. Survey Bench-mark at Pírpanti Railway station fixed by Lieutenant Trotter R.E. in 1864, completing the circuit from Gorakhpur to Pírpanti on the 20th February.

Difference at Pírpanti.

	feet
The height of Great Trigonometrical Survey Bench-mark at Pírpanti railway station as determined by Lieutenant Trotter in 1864	155·03
The value now obtained applying the correction for circuit error at Cawnpur and Dildárnagar viz. + ·552 feet	155·81
Difference	— 0·78

which error to prevent disturbing the values as given in tables already published has been provisionally distributed between Parsoni and Pírpanti. Neglecting the circuit error at Cawnpur and at Dildárnagar the difference of level between Pírpanti G. T. Survey Bench-mark as determined by Lieutenant Trotter R.E. in 1864 and that now determined would be 0·23 feet.

Bench-marks fixed.

(11.) On the line from Parsoni to Pírpanti 97 bench-marks were fixed, of these 5 were bench-marks of the G. T. Survey pattern embedded in the vicinity of trigonometrical stations as directed in Superintendent's memo No. $\frac{19}{1577}$ of the 19th of December 1871; 4 embedded bench-marks (with pillars built to indicate their position) viz. at

Gaumanti, ½ way between Purniah and Náthpur.
Purniah civil station (Collector's Kacheri).
Near 14th iron mile post from Karágola ghát.
Karágola ghát (Post office compound).

of the remainder 59 were paka points, such as wells, temples, &c, on which the letters $\frac{\text{G.T.S.}}{\text{B.M.}}$ were engraved at point where staff was placed; and 24 were iron mile posts on the road from Karágola ghát to Purniah, the staff resting in all cases on the top of the post.

Crossing the River Ganges.

(12.) Some difficulty was experienced in carrying the levels across the river Ganges the narrowest point at Karágola ghát being 30·83 chains, the ordinary divisions of the leveling staves could not be read at this distance, and a foot had to be measured on paper, divided into tenths and half-tenths and then attached to the staves, even these divisions could with difficulty be read with any degree of accuracy, except in the early morning and towards sun down, at which times the refraction is greatest. By multiplying the number of observations and taking morning and evening sets on two consecutive days, alternating the order of observation on the second day the difference of level between the right and left bank of the river was as follows.

By Captain Carter No. 2 level (mean of 54 observations) ..	3·380 feet.
By Mr. Donnelly No. 3 level (mean of 54 observations) ..	3·338 feet.

New circuit from Purniah.

(13.) On the completion of the circuit from Gorakhpur to Pírpanti, the party marched back to Purniah and commenced a new circuit from the G. T. Survey Bench-mark at the Protestant church along the main road form Purniah to Dárjiling as far as the Rámganj tower station at the N. E. end of the Sonákhoda base-line, the tower station of Sonákhoda at the S.W. end of the base-line being also connected; the work was closed for the season at the G. T. Survey Bench-mark embedded in the vicinity of the Rámganj tower station on the 22nd of March. The length of this portion of the season's work was 68 miles and on this line 4 bench-marks of the G. T. Survey pattern were embedded and pillars built to indicate their position viz. at

The encamping ground of Belgáchi
Ditto Assuragarh
Ditto Ghaisal

and at the trijunction of the village lands of Singdhai, Bagaligach and Magdama, near the 94th mile post from Karágola ghát, besides these 17 paka points were fixed and 56 iron mile posts.

The leveling was closed for this season at the Rámganj Tower station on the 22nd of March, the party arriving at Purniah on its return march on the 1st of April; after making arrangements for the safe custody of the instruments, Government stores &c. at Purniah, and furnishing the civil authorities with values of the points fixed in the vicinity of Purniah, as above mentioned, it arrived at Sáhibganj the nearest station on the E. I. Railway, on the 10th April, *en-route* to Head Quarters Dehra Dun, the native establishment (with the exception of 7 men left in Purniah in charge of the Government property deposited there, and a few men required at Head Quarters during the recess) being permitted to proceed on leave with orders to be at Purniah on the 10th November 1872 by which time the country will have sufficiently dried up after the rains, to permit of the operations being continued.

Custody of Paka pillars indicating position of Bench-marks.

(14.) Before leaving Purniah for recess quarters, receipts in duplicate for all paka pillars, indicating the positions of embedded Bench-marks were drawn up and delivered to the civil authorities with the view to these permanent marks being made over to the safe custody of the owners of the ground on which they are built, as in the case of Tower and Platform stations of the G. T. Survey as laid down in Departmental order No. 1 of 15th January 1866, the receipts for these pillars duly signed have been received from the Magistrate and Collector and have been made over to the Officer in charge of the Computing office, the duplicates being retained by the person in charge of the pillars.

State of Trigonometrical stations connected.

(15.) During the season's work the following Tower Stations of the Great Trigonometrical Survey of India were connected viz:—

				Heights of remaining Portion of Paka Pillar
Dighi T. S. (N. Malúncha Series)	..	..	..	.. 7′ 8″
Rámnagar T.S. (N.E. Longitudinal Series.)	..	..	..	.. 13 9
Latona T.S. (Ditto ditto)	..	..	..	.. 27 0
Dewánganj T.S. (Ditto ditto)	..	..	..	.. 14 0
Ghiba T.S. (Ditto ditto)	..	..	..	.. 8 0
Sonákhoda T.S. (Ditto ditto)	}	Sonákhoda Base-line stations.		Perforated Towers complete.
Rámganj T.S. (Ditto ditto)	}			

a statement as to the state of these towers will not be out of place here; the 1st five are of the old pattern towers, namely solid masonry pillars in the centre of mud built towers, in all these cases the kacha part of the tower has fallen, and only so much of the paka pillar remains as given above, under these circumstances the only means of connection was by digging into the paka pillar, about the ground level and reaching the ground level markstone.

The Towers at the ends of the Sonákhoda Base-line viz: the Sonákhoda and Rámganj stations were found in good order, with the exception that the arching over the mark at the Rámganj end was broken in and the mark exposed, this was built over again. The towers were carefully closed, the walls cleared of all shrubs &c. and whitewashed.

Out-turn of work.

(16.) The total out-turn of work during the season has been as follows viz :—

245 miles of double leveling.

7 Trigonometrical stations connected.

16 G. T. Survey Bench-marks embedded and connected.

8 Paka Pillars built indicating positions of embedded Bench-marks.

76 Paka points fixed and the letters $\frac{\text{G. T. S.}}{\text{B. M.}}$ engraved thereon.

80 Iron mile posts connected on road from Karágola ghát via Purniah to Dárjiling.

Drawing of Bench-marks.

(17.) Drawings shewing the position of the leveling staff at 53 of the 76 Paka Bench-marks have been made and will accompany the records of the past field season's work accompanying this report.

(18.) The line of levels protracted on the scale of one mile to the inch will be completed shortly and will then be forwarded.

Conclusion.

(19.) In conclusion I beg to bring to your notice that during the time Mr. Donnelly was in charge of the party his arrangements appear to have been very satisfactory, and subsequently he has assisted me to my entire satisfaction.

The Native Surveyors Amjad Ali and Narsing Dás, have worked hard and in every way deserved my approval.

The health of the party was very good.

Extract from the Narrative Report—dated 27th August 1872—of Major C. T. HAIG, R. E., Officiating Deputy Superintendent 1st Grade, in charge Guzrat Party.

(2.) I received charge of the Party from Lieutenant McCullagh, R.E., on the 23rd September 1871 on my return from England from two years sick leave.

(3.) Captain Pullan and Mr. Connor joined after we had taken the field, the former on 18th December, and the latter on 5th November in place of Mr. A. Bryson who had come with us to Súrat but was then transferred to Captain Campbell's party. On taking the field I also had Mr. Goslin as an assistant, but he left me on 15th December, having sent in his resignation.

(4.) Before reporting on the work done this year it will be as well to state briefly what had been done previous to my taking charge. The whole of the operations of the party were confined to six consecutive Sheets (30' Longitude and 15' Latitude) on the same meridian, excepting, by the way, 5 stations selected and built by Lieutenant Baird, R.E., for a Series of triangles to be run along the course of the river Mahi. Of these six sheets, numbered from 8 to 13, one only (No. 12) had been mapped; No. 8 had been three-quarters covered with net work triangulation and ready for plane tabling; Nos. 9 and 10 had been half got ready; Nos. 11 and 13 had been got ready with the exception of about the space of one plane table, *i.e.*, one eighth of a sheet in each.

(5.) The index map therefore, on which all work done was conventionally indicated, presented rather a patchwork appearance; but this was owing to the extreme difficulty of triangulation in a dead flat country studded with trees varying in profusion from that of an English park to that of a dense forest, so that almost in no instance had a triangulator completed in a field season the portion of work expected from him.

(6.) This was especially the case too in the laying out of the Mahi Series of triangles alluded to above, and although the length of the Series is but 64 miles and it had been worked at for two field seasons, only 7 stations had been selected covering altogether about one-third of its extent.

(8.) Three sheets (8, 11, 13) this year have been topographically surveyed, the blank halves of sheets 9, 10 and also a fresh sheet (14) have been prepared with points ready for plane tabling, so that the index map were it not for the unfortunate loss of a plane table would now present a most orderly appearance, though I am sorry to say it does not admit of any greater out-turn of topography next season than that of this year which is however tolerably fair.

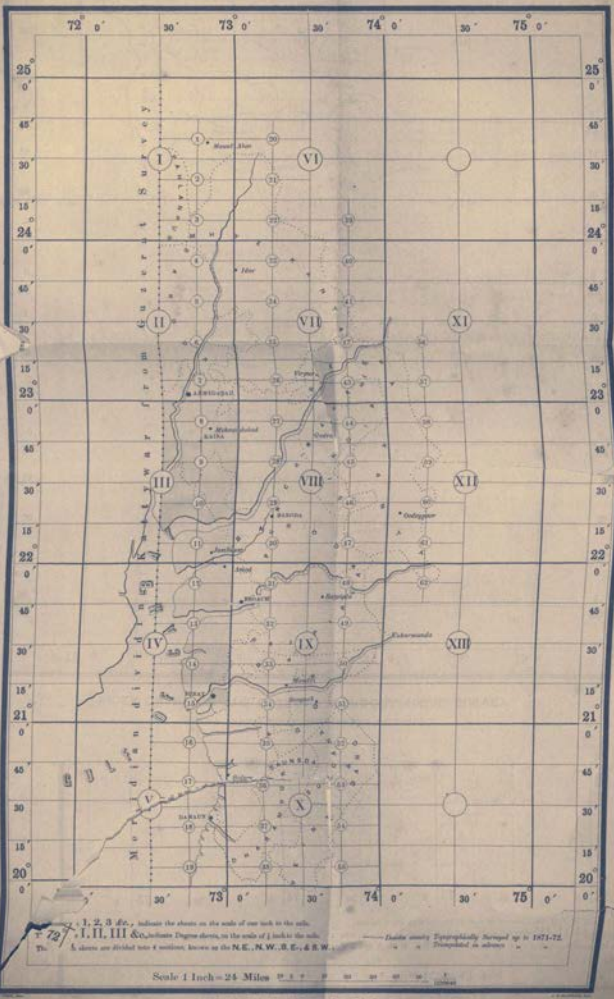
(9.) The lost plane table was being brought to Púna from the field by Mr. McA'Fee. In *Bombay while looking after the safe removal of some theodolites from the Railway van the tin case containing the original plane table must have been carried off by one of the coolies thinking it belonged to another passenger. Mr. McA'Fee took all the means he could think of to recover it, invoking the assistance of the Commissioner of Police and offering a reward of Rs. 50, but hitherto it is still missing.

(10.) I now proceed to details. The Party left Púna on the 23rd October for Súrat where the tents, instruments and field equipment had been stored. At Súrat miscellaneous work, such as preparing and projecting plane tables and bringing up sundry arrears, occupied us till about the 10th November, when, having started off the Assistants to their respective duties, I left for *Kaira visiting Bhroch (Broach) and *Baroda to acquaint the Civil authorities of the general programme of the season's work as far as it concerned their respective districts.

(11.) At *Kaira I took up the question practically regarding the feasibility of utilizing the maps of the Revenue Survey which has been the subject of theoretic discussion since 1867. I have already reported at length in my No. $\frac{S}{82}$ dated 26th January 1872 on the results of my investigations: suffice it here to say that I connected, by traversing, with our triangulation two points in the boundaries of several alternate villages (by alternate I mean separated from each other by *one* intervening village): I then projected these fixed points on a plane table and with a pentagraph traced out on the plane table from the Revenue Survey maps each village, making the corresponding points on the Revenue maps tally with their respective counterpoints already laid down, then I attempted to fit in between the alternate villages thus projected the boundary of the intervening villages from the Revenue Survey village maps. I found, and I was quite prepared to find, that I was attempting an impossibility, but in this way I determined exactly what amount of labour would be entailed in compiling a general map from the Revenue Survey village maps and also the degree of accuracy in the maps thus obtained, and I have as stated above fully reported thereon.

GREAT TRIGONOMETRICAL SURVEY OF INDIA

INDEX CHART OF THE GUZERAT TOPOGRAPHICAL SURVEY



(12.) At *Kaira I was joined by Captain Pullan to whom I had intended giving some triangulation in sheets 6 and 7 for which I had prepared a field chart with all the stations of the Abu Meridional Series included in those sheets projected on it, but I was obliged to abandon that plan on account of Mr. Goslin's leaving, so I entrusted Captain Pullan with the topograhy of Sheet 8. Being an old Kumaon and Garhwal surveyor, he soon brought his experience into play though his work was something new to him, for in place of having several pole and brush marked hill tops continually in view, as is the case in hilly country, here, after leaving a trigonometrical station it requires a keen search on the part of the surveyor to find a spot where he can even see two of his points, so that a very great proportion of the work has to be done on the back and forward ray principle. The scale too was new to him, but he soon got into full swing and then trained a Native Surveyor Bhaw Govind, who had never used a plane table before. He had also working under him Shaikh Kásim a Native Surveyor of 4 years standing, and both of these men are very favorably reported of by Captain Pullan. Shaikh Kásim turned out 172 square miles, and Bhaw Govind 109 square miles which is very fair for his first season and it is moreover extremely neatly drawn. Captain Pullan rigorously examined their work and found it throughout most exact. Captain Pullan himself turned out 242 square miles in his own good style. As he did not commence work till 26th December and Bhaw Govind independently not till 25th January, it was necessary towards the close of the season to send him a reinforcement in order to secure the completion of the Sheet so I gave him assistance which relieved him of one out of his eight plane tables. It is this plane table that has been lost.

(13.) Mr. D'Souza started on his work on 1st November and worked away assiduously covering Sheet 14 with trigonometrical points, until 11th May when he had fixed and taken angles at 98 new stations besides observing also at 13 old stations. His triangulation extended also over above one-eighth of Sheet 15. His work lay in a country thickly studded with villages each of which is a plantation of cocoanut trees, and the villages are so close together that it was generally impossible to lay out triangulation of more than 1½ mile sides, a large portion indeed of his sheet is a forest of cocoanut trees. The number of stations he visited (111) being on the average 18 a month, and the average of his triangular error 8″ speak as to the quantity and quality of his work. Though the area covered by him cannot compare with that ordinarily covered in a season by Mr. McGill in the adjoining *Kattywar Survey, still it is very creditable considering the extreme flatness of the country combined with the almost uniform obstruction of the cocoanut trees. In the course of his work, he extensively connected stations of the Súrat city survey with his triangulation which will enable me to prepare a very accurate map of Súrat without much labour. At the close of the season Mr. D'Souza also inspected and tested a couple of plane tables sketched by Luxumon Ghorpuray and Vital Vishnu.

(14.) Mr. Christie was placed in charge of the Mahi Series of triangulation, which he has completed after a season of almost continuous tardy up hill work beset with the obstacles of a dense forest through which most of his rays had to be cut. As before mentioned several of the stations of this Series had been selected, rays partially cut and some of the stations built before this year, so that Mr. Christie was in a measure committed to take in hand and complete a lot of half finished work which had previously been left unfinished owing to the great difficulties of clearing rays through dense jungle and to the opposition of the Gaikwár's subjects; 6 stations had previously been selected at the south end of the Series and 5 at the north, and out of the 22 rays between these stations 8 had been cleared and 1 partially cleared. But these triangles had too long sides, they varied between 7 and 10 miles and it is impossible to know whether a ray of that length merely determined by signal fires crossed a village midway or not. Mr. Christie found one of these rays that had been previously partially cleared was quite impracticable owing to its crossing a village in the forest and it was also impossible to shift the ray slightly on either side, for the latent village was one of three in *echelon*, so that a complete change in the arrangement was necessary entailing the rejection of 2 stations and 4 rays which he had nearly cleared. Mr. Christie, apprehending this danger of determining rays by signal fires, laid out the new rays after this on the ray trace system, but as soon as he got clear of the previously selected stations he contracted the width of the Series by shortening the sides so as to take as much advantage as possible of the open space of the river itself. By this means and with the assistance of Mr. McA'Fee during the months of May and June, he succeeded in completing the Series. That part of it which is entirely his own, though double the length of the portions at the extremities put together only occupied him four months in selecting and clearing whereas he was occupied 3½ months on that part which was supposed to have been already laid out. The final angles he observed with a 10″ Theodolite by Troughton and Simms working to two pairs of Zeros $\frac{0}{180}$ and $\frac{30}{210}$ using luminous signals throughout. There is however one slight inconsistency in the Series. The observations at one station (*i. e.* two angles) were taken by Mr. McA'Fee with a 6-inch Troughton and Simms' Theodolite. This happened through the extreme difficulty of crossing the Mahi which was much flooded, and Mr. Christie

thought it best as Mr. McA'Fee was on the other side of the river for him to take the observations and save probably a week in the completion of the series. It was then near the end of June. The side of emanation is Poída-Ghorárão of the Guzrát Longitudinal Series—a Principal Series run by Lieutenant Nasmyth with an 18" Theodolite—and the side of verification is Sarod-Duháran of the Guzrát Coast Series—a Secondary Series run by Mr. D'Costa with a 12" Everest Theodolite.

The following Tabular Statement will shew at a glance the quantity and quality of his work.

Stations Selected, ...	11
Miles of ray cut, ...	149
Ditto trace traverse, ...	36
Stations observed at, ...	24
Triangles with 3 observed angles, ...	23
Intersected points, ...	7
Heights fixed, ...	20
Mean Triangular error, ...	4".3
Error of closing (side = 5·493 miles), ...	0".3 feet.
Length of Series, ...	64 miles.
Area Triangulated, ...	400 sq. miles.

(15.) Mr. McA'Fee was appointed to cover the blank portions of sheets 8 and 9 with fixed points for the plane table Surveyors either by triangulation or traversing, extending the triangulation, wherever he could do so without much ray-cutting but substituting traversing for triangulation in close and thickly wooded country. As sheet 8 was to be topographically surveyed during the season, he of course took up that sheet first and on the completion of the field portion of this work he had to stop and reduce his observations. In sheet 8 he fixed 5 new trigonometrical stations and visited 4 old ones and ran 136 miles of traversing fixing a sufficiency of points. In the traversing he was assisted by Gopál Vishnu a traverse Surveyor transferred from the *Kattywar party. Mr. McA'Fee was attacked with fever against which he battled, but he was at times unable to work by reason of it. He had it off and on for rather more than a month so that he was not ready to start on sheet 9 till 19th March by which time he furnished Captain Pullan, who by the by worked with him for one week computing—with all the points required in the eastern plane tables of sheet 8. During the season he also took observations at 5 stations (disconnected with his triangulation) where vertical angles were wanting, in order to compute the heights of a portion of last year's net work triangulation which by some oversight could not be computed for want of vertical observations at two or three stations connecting that season's work with the old triangulation. On the 21st April he took up the sketching in a plane table in sheet 8, the one afterwards lost, in which he sketched 40 square miles, exercising the while supervision over the traversing which was being carried on in sheet 9 by Gopál Vishnu and Ganesh Bápúji (1st) who was sent to work the available traverse party left vacant by Mr. McA'Fee taking the plane table party which arrangement was consequent on Mr. Hickie falling sick leaving a plane table party vacant. Altogether his traversing amounts to 309 miles giving an average of rather more than one point per 2 square miles. After completing the plane table he joined Mr. Christie and assisted him in clearing the rays and selecting stations on the Mahi Series so that he did not return to recess quarters till 4th July along with Mr. Christie.

(16.) Mr. Connor had to complete the net work triangulation in sheet 13 and visit a chain of stations of the previous season's triangulation for the purpose of taking vertical observations which had been altogether left undone, which he finished by 29th December having laid down 37 triangles and taken verticals at 23 stations besides. The area covered comprised 58¼ square miles over which he laid down altogether 50 new fixed points. There was also a traverse of 8¼ miles run in ground thickly wooded. On the completion of the field portion of this work he had to reduce his observations, compute his triangles and the latitudes and longitudes of his stations and points, because sheet 13 is one of those sheets that have been topographically surveyed this year. For these reductions I therefore directed him to join Mr. Cusson to whom the topography of the sheet was entrusted and the two worked together for a mouth and a half when he commenced the traversing of the blank portion of sheet 11 which has also been topographically surveyed this year but after spending a few days on that work during which he fixed one station by triangulation and ran 26 miles of traverse, I sent him on to sheet 10 to cover the blank eastern half with fixed points by traversing or by triangulation if practicable. I gave him a Native Surveyor with another traversing party to run minor traverses, Ganesh Bápúji (1st) who was afterwards succeeded by Ganesh Bápúji (2nd) and altogether that half sheet has been decorated with 154 miles of traversing giving on an average 1·3 fixed points per square mile. The whole of the half sheet is thickly wooded which rendered triangulation impracticable.

(17.) Mr. Hickie was entrusted with the topography of sheet 11 and under him were placed two Native Surveyors Balwant Govind and Mukund Dinkar each with a plane table and

TABULAR STATEMENT OF WORK IN GUZRAT DURING THE FIELD SEASON 1871-72.

Triangulation.

Observer's Names.	Instrument used.	Area triangulated.	No. of stations visited.	3 Angles observed.				2 Angles observed.			Remarks.
				Triangles.	Triangular error.	Error per mile.	No. of Heights.	Triangles.	Error per mile.	No. of points.	
					″	feet			feet.		
Mr. A. D'Souza, ...	6″ by Troughton & Simms	536	111	145	8	0·1	62	765	0·09	481	Only a very few triangles yet computed.
„ A. Christie, ...	10″ ditto	400	25	23	4·3	0·05	21	9	2·3	7	The Mahi Series.
„ C. H. McA'Fee, ...	6″ ditto	38	11	7	8·8	0·6	6	19	5·0	15	
„ E. J. Connor, ...	6″ by Cooke & Sons	62	51	38	11	0·52	51	42	1·7	32	
	Total,.....	1036	198	213	...	...	142	835	...	535	

Plane Tabling.

No.	Names.	Plane Tabling.	Stations per square mile.	Remarks.
1	Captain A. Pullan, S.C., ...	242·0	7·1	The cost per square mile of Topographical Survey Rupees 46-12-2.
2	Mr. C. H. McA'Fee, ...	40·0	8·2	
3	„ J. Hickie, ...	126·0	13·6	
4	„ D. Cusson,...	190·0	7·4	
	Native Surveyors.			
1	Shaikh Kásim luya, ...	172·0	7·6	
2	Luxumon Ghorpuray, ...	177·0	9·6	
3	Balwant Govind, ...	166·0	13·2	
4	Mukund Diukar, ...	64·0	14·5	
5	Vital Vishnu, ...	96·0	9·5	
6	Bhaw Govind	109·0	12·1	
		1382	10·3	

Traversing.

No.	Names.	Linear miles of traverse.	Remarks.
1	Mr. C. H. McA'Fee, ...	91·3	Check Azimuths observed at 7 stations.
2	„ E. J. Connor, ...	179·3	
3	„ J. Hickie, ...	13·9	
	Native Surveyors.		
1	Gopál Vishnu, ...	148·4	
2	Ganesh Bápuji, 1st	82·5	
3	Ganesh Bápuji, 2nd	80·0	
		595·4	

party. The latter being a new hand, Mr. Hickie had first to train him to the work not quite *ab initio* as he had received some instruction last recess from Mr. D'Souza. Mr. Hickie was very unfortunate in losing his health which I fear will render him a delicate subject for some time to come. He had some years previously been a victim to chronic diarrhœa but had while serving on this side of India been enjoying an immunity from it until last December when it was again induced by the work on the coast which he sketched himself and where he was frequently for hours with his feet wet in the mud; that and the sun over head brought back his complaint which weakened him very much. When I visited him in January I noticed he was looking very much pulled down, but he continued to battle against the disease and worked on till 1st March when he was obliged to come into Bhroch for medical treatment which afforded him relief for the time, on which he resumed his work until the middle of April when he was obliged to give up and come again to Bhroch and then the Civil Surgeon discovered that his complaint was much more serious than he had at first supposed. He was for a short time very seriously ill but he was restored to comparative strength again and I then, during the remainder of the season, employed him on sedentary work in my office, fair copy of angle books &c. During the field season he with his own hands sketched with the plane table 126 square miles and closely inspected the work of both Balwant Govind and Mukund Dinkar who respectively turned out 166 and 64 square miles. The latter was employed from the 18th April under Captain Pullan. Mr. Hickie was also employed for about a fortnight traversing as the eastern portion of sheet 11 was too scantily provided with points.

(18.) Mr. Cusson was entrusted with the topography of sheet 13 and under him were Luxumon Ghorpuray and Vital Vishnu, the former a lad trained during the previous season, the latter a newly entertained lad. Mr. Cusson kept Vital Vishnu working with him until 15th December when he started him independently. Mr. Cusson as I have stated in para. (16) was interrupted in his topographical work by having to compute with Mr. Connor for a month and a half and again on 20th March when there were but two plane tables to be completed in sheet 13 which were made over to Luxumon Ghorpuray and Vital Vishnu, I directed him to take up a plane table in sheet 8 which he had half completed when Mr. Hickie's falling sick necessitated another change and I sent him to take Mr. Hickie's place, relieving him in sheet 8 by Mr. McA'Fee as mentioned in para. (15). Altogether Mr. Cusson with his own hands turned out 190 square miles of topography.

(19.) I have thus the pleasure of reporting favorably of the whole of my Assistants, every one of them having worked zealously and well, and the result of their combined labors must be considered highly satisfactory, comprising as it does the Topographical Survey of three sheets and the completion of the preliminary preparation of a similar area for topographical sketching next season, besides the completion of the Mahi triangulation. This considering the tender age of the party is I consider very successful.

(20.) I have also the pleasure to report the absence of any serious collisions with obstructive or litigious natives which, after the reports of Colonel Nasmyth and Lieutenant McCullagh, is I consider matter for congratulation.

(21.) Great obstruction was anticipated and indeed had been previously experienced from H. H. the Gaikwar's subjects in regard to cutting trees, but I represented through the Resident at Baroda the fact that most of the other large states in India had handsomely contributed towards defraying the cost of the Survey of their territory and suggested it would be after all but a trifling contribution on the part of the Baroda Darbár to relieve us of the *onus* of settling and awarding compensation for trees &c. This representation produced the desired effect and the Darbár sent me a Wakíl (whom I attached to Mr. Christie's camp) to settle all difficulties in the way of cutting trees and to deal with all claims for compensation as claims against the Darbár and thus no further difficulties were experienced.

Extract from the Narrative Report, dated 14th August 1872—of Captain W. M. CAMPBELL, R. E., Officiating Deputy Superintendent 2nd Grade, in charge No. 2 Extra Party.

In the report which I submitted on 21st September last, giving a sketch of my employment on special duty in England during the preceding nine months, I mentioned that the new Zenith Sector with other instruments had just arrived in *Bombay, and I shortly afterwards informed you that all these instruments had reached me at Púna in good order.

According to my instructions I despatched the instruments appertaining to the Electro-Longitude equipment to the care of Captain Herschel at Bangalor, and I sent an astronomical clock to your address at Dehra Dun, while I made all preparations for using the Zenith Sector for my own latitude observations during the approaching field season.

(2.) The work assigned to me was, to take observations for latitude on the Mangalur Meridional Series at points as evenly distributed as possible between Kem H. S., in latitude 18° 11′ (where Lieutenant Heaviside had closed his series of observations) and Mangalur in latitude 12° 53′ at which place I was instructed to choose a station, which should be also suitable for the proposed Electro-Longitude observations.

The average distance between latitude stations having always been considered as 1°, you advised me in case of the nature of the country requiring greater intervals, to endeavor to obtain two, or even three stations suitable for observation in each locality.

(3.) I had the following information to guide me in my selection of stations,—1st under instructions from Lieutenant Trotter, Mr. Wood had reconnoitred the neighborhood where it was advisable to select the first station south of Kem, and reported that out of 12 stations visited by him, Majála in latitude 16° 47′ was the only one that seemed suitable.

2nd. Lieutenant Trotter who had himself executed the triangulation from latitude 15° 30′ to latitude 14° 26′ told me that he thought Kundgorl in latitude 15° 15′ was the only point suitable for latitude observations in that portion.

These two stations being decided upon, and that at Mangalur being obligatory, it only remained to find a fourth point about latitude 14° to complete the set, dividing the total distance of 5° 18′ into four intervals averaging 1° 20′ each.

Accordingly this was the course I fixed upon, with the intention of using two stations in each locality if the nature of the country would admit of it.

(4.) The principal triangulation of the series from latitude 14° 26′ to Mangalur, and again that of the Longitudinal Series for some distance east of Mangalur, had not been executed at the beginning of last field season, and as it was a matter of considerable importance that the latitude station at Mangalur should not only be equally suitable for the longitude observations, but should also be a station of the principal triangulation, or at least be capable of easy connection therewith, the best course appeared to be to proceed myself at once to Mangalur and select the station to answer if possible all these requirements.

This arrangment was also convenient, because it admitted of my returning from Mangalur, through the district about latitude 14° where I wished to select a latitude station, to meet the Party, (which should in the meantime have marched from Púna under charge of my assistant) at one of the points already fixed on viz. Majála and Kundgorl.

(5.) In accordance with this programme I despatched the camp from Púna under charge of Mr. Bryson (who had only just joined me from the Guzrát Party) with instruction to proceed to Kundgorl and prepare that station for observations.

The choice of Kundgorl, for the first station to be observed at, involved a return march northward to Majála, but it was the more convenient course for several reasons, chiefly because it suited my movements best with regard to time, and also gave me more opportunity of seeing the localities to be worked in, before committing myself irrevocably to any one station.

(6.) I left Bombay for Mangalur by steamer on 19th November taking my servants and camp equipage with me as far as Kamte (Coompta) where I landed them with instructions to proceed to Gursuppa by boat and there await my return from Mangalur.

(7.) On arrival at Mangalur I found a party of signallers with their heliotropes, sent to meet me by Major Branfill at my request. I lost no time in sending these men out to the 3 adjoining stations of the approximate triangulation, with which I wished if possible to

connect my proposed latitude station, substituting it for the station of the approximate series nearest to Mangalur, which being 4 or 5 miles distant from the Telegraph office, I did not consider suitable for the Electro-Longitude observations.

The Telegraph office is so very low lying and hidden from the surrounding country by higher ground and trees, that fixing trigonometrically any point in its neighborhood would have involved very considerable expenditure.

After some trouble I succeeded in finding a point to satisfy all requirements, close to the lighthouse and within a mile of the Telegraph office, and therefore capable of temporary connection therewith at slight expense.

(8.) Taking the first steamer available I reached Kamte on 28th November; and thence joined my people at Gursuppa next day.

From Gursuppa there is an excellent road over the Ghâts to the north-west corner of Mysor, where I made a hurried inspection of the stations of the approximate series which seemed available for my purpose.

The season was so far advanced that I could not afford to spend so much time over this as I could have wished, but I satisfied myself that at least one station was fairly suitable, and then hurried northward as rapidly as possible joining the Party at Kundgorl on 16th December.

(9.) Some days were lost in consequence of the station not being ready to receive the observatory tent and instrument, and observations were not finished till 30th December and I started for Majâla on 31st December. In the meantime I had deputed Mr. Bryson to examine the two neighboring stations Indúr and Ganígud with a view to taking observation at one or both, but he reported them as unfit. I then sent him in advance to Majâla to prepare for the work there.

(10.) On the march, I took the opportunity of inspecting the station Naolúr next adjoining Kundgorl to the north, and finding it very well adapted for my purpose, resolved to take a set of observations there on my return from Majâla.

(11.) The Party reached Majâla on 12th January and again I was delayed for 2 or 3 days owing to the difficulty of getting work done promptly. I sent Mr. Bryson to examine two stations Dandoba and Mawinhunda adjoining Majâla, which Mr. Wood had not been able to visit the year before, and he reported that the latter was suitable for a latitude station. I had preparations made accordingly and after completing work at Majâla proceeded to Mawinhunda and finished observation there on 7th February.

(12.) From Mawinhunda the Party returned south to Naolúr, where I took a set of observations and then revisited Kundgorl for a second set, which appeared to me desirable because of the adoption of some changes in the method of observation (which will be noticed later) after the first visit.

(13.) I finished work at Kundgorl on 9th March, and marched southward, whither Mr. Bryson had preceded me with instructions to examine the two stations which I thought likely to be suitable, and prepare them for observation if his examination proved satisfactory, which he did and I took a set of observation on each. These stations which I have named "Hunawali" and "Koramoraguda" are not as yet fixed by triangulation, which was closed at Chanderguti a few miles to the north by Lieutenant Trotter in 1867 and has not been continued since, but they both belong to the approximate series, and are likely to be fixed next season viz. 1872-73.

(14.) After Mr. Bryson had finished the preparatory building at these stations, as I did not expect to require his services at Mangalur, I sent him northward to re-protect and re-transfer the stations at which I had taken observations, as well as any others which he might find to require it.

(15.) I was terribly delayed at both Hunawali and Koramoraguda by clouds and fogs, the latter of which driving up from westward every night, used to put a complete stop to observations generally as early as 11 P. M., and did not clear off again till the sun got high in the heavens next morning.

These fogs may interfere with the triangulating party more seriously than they did with me, as they envelope the hills and obscure terrestrial objects generally some time before they close overhead and stop star observations.

They commence early in the hot-weather and increase in intensity as the season wears on, being also worst in the neighborhood of the Ghâts.

(16.) I did not finish observations at Koramoraguda till 13th April, when I marched for Gursuppa, having decided that much the most convenient and economical route for transporting the Party to Mangalur at that season, was by the good Ghát road to Gursuppa and thence by boat down the river to Honawar and by native sailing vessel to Mangalur. The journey was made successfully and the Party reached Mangalur on 22nd April.

(17.) I put up the instrument a few feet due east of the Trigonometrical station, which being on a pillar several feet in height was not suitable.

Here again, clouds rendered my life a burden to me, for night after night I got either no work at all or only two or three observations; and in the end I considered myself very fortunate in completing my observations on 17th May; but I was forced to give up the idea of observing at two or more supplementary stations as I had proposed doing.

(18.) On 21st May I left Mangalur by steamer for Bepur (Beypore) and thence came on to Bangalor by rail, arriving on 24th May.

(19.) I shall now give a slight description of the stations which I visited.

"Majála" and "Mawinhunda," are both situated on flat-topped isolated hills standing in a plain, the general level of which is very equable.

The hill at Majala is about 560 feet above the plain, at Mawinhunda about 540 feet. At the first there is a slight preponderance of matter to the North and in the latter to the South, but in neither case is there any reason to expect appreciable disturbance of the plumbline.

(20.) "Naolúr" is on a low sharp peak, 100 or 120 feet above the level of the plain, which is, in the immediate neighborhood, rather broken by undulations.

"Kundgorl" stands on a slight swell in the middle of a very gently undulating plain. The general level of the country surrounding both of the last stations is very equable. In neither of these do I see any reason to assign a preponderance of matter on one side or the other, far less to expect any appreciable influence on the plumbline.

(21.) "Hunawali" and "Koramoraguda" are situated on hills in an undulating country of equable general level, but considerably broken up by hills, detached in groups, or in small ranges running inland from the Ghâts. The country to a great extent, and the bases of both the hills in question, is covered with jungle.

The station "Hunawali" is on the highest point of a sharp ridge running North-East and South-West; its height above the plain is about 770 feet. There is probably some slight preponderance of matter on the southern side below the hill, but the hill itself has a small excess to the North.

"Koramoraguda" is on a round topped hill about 450 feet above the plain, the highest point of a little range running nearly East and West. There is a slight excess of matter in the plain below the hill to the South, and the mass of the hill itself is rather greater to North than to South of the station.

(22.) At neither of these stations do I think there is any thing sufficient in the configuration of the ground to justify a guess as to the direction of irregular attraction; but it must be remembered that they are both in the neighborhood of the Western Ghâts and the great drop from the Mysor plateau into the low country of Kanara, averaging fully 2000 feet. This change of level is to the West, and several miles distant in both cases; but its line trends south-eastward and therefore the deficiency of matter caused thereby also lies to the south of the stations, but at a much greater distance from them in that direction.

(23.) The station at Mangalur is on the lighthouse hill, about 160 feet above the sea. There is nothing in the features of the ground in the vicinity sufficient to cause irregular attraction, but the mass of the high country above the Ghâts lies to the East and North-East and the sea to the West.

(24.) I shall now make some remarks on the method of observation and on the instrument.

In the first set of observations at Kundgorl I made no use of the capability of the instrument for change of zero, but I introduced this at Majála.

(25.) In the middle of my observations at the latter place I had a letter from Captain Herschel in which he informed me, that he had tried the experiment of reversing his

instrument bodily, with so decided an effect on the results that he considered such reversal proved to be almost essential. I had long before comtemplated making this reversal among others, but was deterred owing to the labor it involved of taking the instrument entirely to pieces, which labor however Captain Herschel avoided by the expedient of revolving it, all standing, on a metal fulcrum introduced under the centre of its base plate. The morning after receiving his letter I reversed in this manner and have done so ever since, taking half the observations at a station in each position of the instrument.

(26.) At Mawinhunda I farther introduced a reversal of the sector with regard to the microscopes. This change was a very troublesome one and its advantage problematical, but after adopting it I continued it at three stations, and then abandoned it, because I found that with uncertain weather, such as I had at the latter end of the season, every change of this sort, which divided the total observations to be obtained into groups, each to be taken in its own position, became a fertile source of delay.

(27.) At one time I adopted the plan of changing the order of position (East and West) of observation with alternate stars, at another on alternate nights. Both methods I think have arguments in their favor, but I am now of opinion that the former is the best. It is the one that Captain Herschel has adopted.

(28.) Early in the season I gave up all attempt at selecting stars in "pairs" with your sanction, and made it my first object to obtain stars depending on the greatest number of observations at Greenwich, using for this purpose both the seven-year Catalogues of 1860 and 1854. At the same time I always used an equal number of stars North and South of the Zenith, and endeavored to maintain an equality between the mean Zenith Distance, North and South.

The importance of using "pairs" seems to me to be almost entirely removed by the introduction of changes of Zero, whereby (excepting chance coincidences) a fresh set of graduations is used for every observation, whether of the same star or not.

(29.) I have discovered only one feature of the instrument which gave me uneasiness, viz., an instability of the zero of levels and microscopes, and level of transit axis, which have a tendency to change all together. I attributed this want of stability to the fact that the frame or "cradle" carrying the levels and microscopes and supporting the transit axis, stands upon four bearings, exactly equal pressure on which it is impossible to maintain. The contact is effected by a steel bolt assisting gravity and working through a thick brass plate. Consequently as the temperature varies the tension of the bolt and therefore the pressure of the cradle on its bearings also varies, and these bearings not being exactly in the same plane, or not all equally rigid (two being provided with an adjustment) strains are set up, causing the changs of zero noticed, between which and the temperature of the observatory I traced a decided connection.

(30.) When I first noticed these changes they caused me some anxiety but I have not traced any injurious effect in the zero error given by each observation, and it must be recollected that the most valuable feature of this instrument is, that any change of the sort is of no consequence whatever, provided stability may be reckoned upon for the time occupied by one double observation or for about 5 minutes only.

(31.) Throughout the season the instrument was carried on spring carts, which I constructed for that purpose at Púna, with a very great saving in pay for bearers, as these carts were dragged by the Khalásies of the Establishment, aided when requisite by ordinary coolies. They answered their purpose admirably and passed over some very bad, rough tracks, not worthy the name of road.

(32.) I regret that I am not in a position to judge of the observations by their results, which owing to the small computing power of the Party, have not yet been arrived at. The progress of the work has been greatly impeded by the necessity which I found myself under of recommending the grant of one month's privilege leave to Mr. Bryson, on very urgent private affairs.

(33.) Mr. Bryson only joined me at the commencement of last Field season; indeed he had already taken the field with the Guzrát Party, when he was transferred. He was therefore quite inexperienced in the work which he has had to perform.

I am very glad to be able to speak highly of his capacity and willingness to learn new duties and of his zeal in performing them, and I have nothing to complain of but a slight tendency to overlook details.

(34.) Nearly all the recording was done by my native writer, who is a very useful and hardworking observatory assistant.

(35.) I shall conclude this report with a short *résumé* of the season's work. The Party left Púna, on the 9th November and marched under charge of Mr. Bryson to Kundgorl H.S. close to *Dharwar, where I rejoined it on 16th December, having in the interim visited Mangalur and selected a station there.

Between the 16th December and 17th May, observations were taken at seven stations and a second set at one of them, the distance travelled during that time being about 450 miles by land and 100 by sea. The weather during the early part of the season was favorable for observation, but in April and May very much the reverse.

(36.) The following is a statement of the cost of the operations.

The total cost of the Party during financial year 1871-72, was Rs. 17,788, which divided between 8 determinations of latitude, (including a second of one station) gives the average cost Rupees 2,223-8-0. This average however is not a fair one; as during the first five months of the year the pay of the officer in charge (Lieutenant Trotter acting) was not debited against this Party.

Extract from the Narrative Report—dated 6th September 1872—of Captain T. T. CARTER, R.E., Deputy Superintendent 2nd Grade, in charge Brahmaputra Series.

PERSONNEL.

Mr. W. G. Beverley (in charge) Asst. Supdt. 2nd Grade.

ASSISTANTS.

Mr. C. T. Neuville, Surveyor 2nd Grade.
Mr. G. A. Harris, Asst. Surveyor 1st Grade.
1 Native Doctor.
51 Kalashies.
15 Barkandáz Guards.

(1.) The Party as per margin left *Calcutta on the 18th of November 1871 in charge of Mr. W. G. Beverley (who was also in charge of the Eastern Frontier Series) arriving at Kálíganj on the Bráhmáputra River on the 28th of the month, where Messrs. Neuville and Harris landed to carry out the instructions as conveyed to them by Mr. Beverley.

(2.) In accordance with the programme of operations submitted for approval to the Superintendent G. T. Survey of India in Mr. Beverley's letter No. 106 of 1871, Mr. Neuville was to complete the approximate series fixing definitely the sites for the Alangjáni and Gobindpur Tower Stations, as some doubt existed whether the positions originally fixed for these Stations by Mr. Beverley in the Season of 1870-71 would last owing to the encroachment of the river. Mr. Neuville was then to fix the position of the Rangira Hill Station and visit the hill station of Gáropára to see if the rays to the plains were clear, subsequently Mr. Neuville was to examine the rays

Narsingbhanj	to Kashdoho.
Kashdoho	„ Kanchípára.
Gáropára	„ Kanchípára.
Gáropára	„ Halka-Char.
Gáropára	„ Janákípur.

and if necessary make the final clearings.

(3.) At the completion of this approximate work, Mr. Neuville was to take up a minor triangulation to the Civil Station of Maimansinh if time permitted, if not, he was to pay the compensation due on the above mentioned rays. Mr. Neuville carried out these instructions. The station of Alangjáni was found intact and a position chosen for a new tower to be built at Gobindpur, in place of the site originally selected up to which the river had encroached to within 40 feet. The final rays above described were cleared and compensation for trees paid.

(4.) The completion of the approximate work occupied Mr. Neuville to the 15th of February, when he proceeded to take up the minor triangulation to Maimansinh, on the side Poerbari

to Rashidpur of the Bráhmáputra Series, but as time would not have permitted him to have completed the triangulation as far as Maimansinh during the season, and the 12-inch Theodolite with which he was to have done the work had not arrived, it was abandoned after taking trial rays for the 1st triangle of the series. He then proceeded to pay compensation for trees cut, in accordance with Mr. Beverley's instructions as above mentioned. This occupied Mr. Neuville till the 15th of April, when he proceeded to Calcutta and thence to Head Quarters, Dehra Dun, arriving on the 9th May.

Approximate work.

(5.) The approximate work has been completed (with the exception of building certain towers and platform stations to be afterwards enumerated) and the rays cleared up to the junction of the series with the Assám Longitudinal Series. Mr. Neuville's work during the past field season is I think deserving of commendation.

Bonarpára, Kanchípára, Bhatibochágari.

(6.) Mr. G. A. Harris on landing at Káliganj on the 28th November proceeded to complete the building of the tower stations of the Series, but having completed the Tower Stations as per margin, he was directed to proceed and take up the building of the pillars on the Eastern Frontier Series, leaving Káliganj for *Gowhatty on the 24th of February.

Tower and Platform Stations to be built.

(7.) There remain to be built the following Tower and Platform Stations namely, at Kashdoho, Narsingbhanj, Gobindpur and Alangjáni stations, and 5 Platform stations, *viz.*, at Gáropára, Peshkarbhita, Rangira, Singimari and Samding.

(8.) The side of continuation for the ensuing season's work, will be Parkoksa to Poelsa of the Basalia Polygon, but Mr. Neuville reports that there is much fear that the station of Parkoksa will have been carried away by the river during these rains, in which case a new pillar will have to be built in the vicinity of Parkoksa and two triangles re-observed in the Basalia Polygon.

Captain Carter takes charge.

(9.) The charge of the Party was made over to me, vide Departmental Order No. 21, dated the 13th May 1872. The information given in this report is chiefly derivable from Mr. Neuville the Senior Assistant with the party. The Party will take the field towards the end of October and an endeavor will be made to complete the work by the end of the field season 1873-74. There remain 3 Hexagons, 2 Pentagons and a Quadrilateral to complete the Series.

Health of the Party.

(10.) I regret to say that Mr. Neuville, on the return of the Party to Head Quarters, was obliged to avail himself of two months privilege leave to recruit his health which he wishes to state has suffered severely during this, as well as the previous field season. Of the Native Establishment, about 20 per cent were generally ill with fever or dysentery.

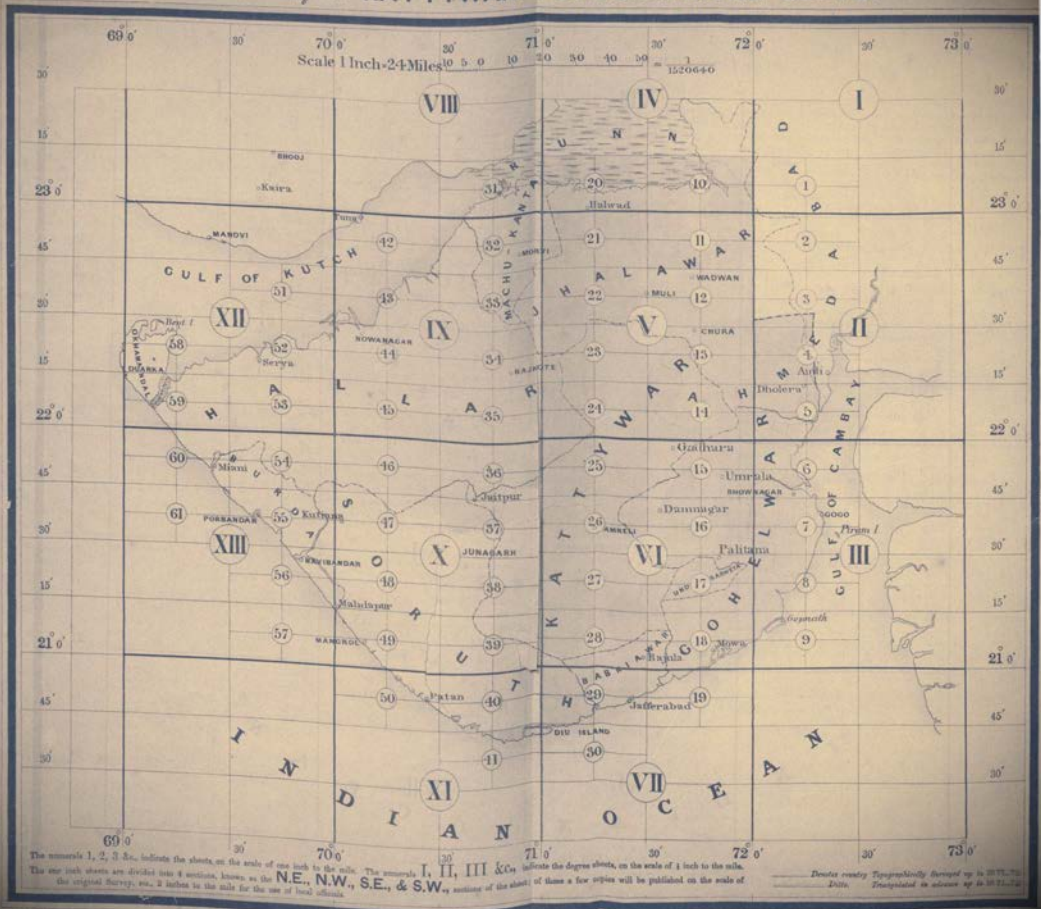
Extract from the Narative Report—dated 14th September 1872—of Captain H. TROTTER, R.E., Deputy Superintendent 3rd Grade G. T. Survey, in charge *Kattywar Survey.

(3.) The Party left recess quarters at Púna about the 20th October, all the Assistants and Native Surveyors, proceeding as usual by rail to Súrat, thence across the Gulf of *Cambay by bandar-boat to *Gogo, our starting point for the interior of Kattywar. A few days march took them to the ground they had to survey and nearly all had commenced work by the 20th November.

(4.) I returned myself to Púna from privilege leave on the 9th November, the arrangements for taking the field having been ably conducted during my absence by the Assistant Superintendent Mr. McGill. Mr. Fielding had remained behind in Púna under my instructions to complete some of the mapping and records: and by the 14th November, I was able to despatch to Head Quarters, for publication, the whole of the fair copies of the maps completed during the previous season viz. sheets XXVI, XXVII and XXVIII of the Kattywar Survey scale 2″ = 1 mile.

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

Index Chart of the KATTYWAR TOPOGRAPHICAL SURVEY



(5.) On the 15th of the same month Mr. Fielding and I started for the districts and on arrival at *Bombay, were somewhat alarmed at reading a paragraph in the newspapers to the effect that a tremendous storm had swept over the Gulf of Cambay on the 12th, and that many vessels had been wrecked, especially between Súrat and Gogo; that the sea wall at the latter place had been washed away and a great amount of damage done; that a number of tents had been swept away, amongst them those of an assistant in the Trigonometrical Survey. This was so far satisfactory, in that it was probable that the assistants had safely arrived; but knowing that the usual camping ground at Gogo was situated immediately behind this very sea wall, and fearing that very probably the whole of our tents, instruments, stores, records, &c. (which had been despatched by country craft direct from Bombay along with the Subordinate Native Establishment and the Assistants, and my own horses) might have been deposited there as usual, I was naturally very anxious until, on my arrival at Gogo on the 20th, I learned, that by a great piece of good fortune, owing to the unhealthy state of the camp followers, Mr. McGill had directed the whole of the Head Quarters camp to await my arrival at Wartej, about 12 miles inland, instead of at Gogo, where I had expected to find them. Thus no harm or damage was done to Government or to my own *property*; but Mr. Fielding's tent had unfortunately been pitched in the usual place and he found, on his arrival, everything that he had more or less injured by the salt water. His tents and boxes had been carried away by the force of the waves and had been deposited at a considerable distance off, close by the missionary's bungalow. Altogether, however, it is a source of congratulation that so little damage was done. Had the storm occurred a few days earlier the consequences might have been most disastrous.

(6.) Mr. Wyatt left Púna at the same time as the other Assistants, proceeding from Bombay by pattimar (country-boat) direct to Jafarabad, a port on the sea coast of Kattywar situated in sheet XXIX, a portion of the survey of which sheet had been left unfinished the previous season and which I had deputed Mr. Wyatt to complete.

(7.) The whole of the Assistants worked steadily and well throughout the season which may certainly be considered to have been a successful one, the actual amount of work completed being as follows :—

Amount of work done.

(8.) 2036 square miles have been topographically surveyed on the scale of 2" to the mile, 1940 square miles have been covered with a net-work of triangles preparatory to topographical survey, 779 linear miles of Täalluka boundary have been traversed with theodolite and chain, every boundary stone having been fixed, besides which 156 linear miles of traverse have been run along the margin of the season's work to test the accuracy of the detail survey.

(9.) The majority of the plane tablers commenced work in sheet XXV and worked steadily northwards, completing before the end of the season the whole of the topography of sheets XXIII, XXIV, and XXV, a very satisfactory out-turn of work considering the number of hands employed (viz: five European Assistants, two of whom were quite new to the work, and five Natives of whom one was a raw-hand). The ground in sheet XXV was mostly flat with the exception of one plane table, but in the sheets to the north there was an enormous amount of detail, requiring a large expenditure of time and labour to survey. Had it not been for this I might probably have a still little larger out-turn of work to record; for the past season has happily been an unusually healthy one and there was comparatively little sickness in the field though I regret to say there has been a great deal since our return to quarters.

(10.) Whilst the majority of the Assistants were employed in those three sheets, Mr. Wyatt was hard at work in sheet XXIX where he had first of all to complete a piece of triangulation, then run some traverses, and finally complete the topography of that portion of the sheets XXIX and XXX which was left unfinished last year. This was all completed satisfactorily before the end of May.

(11.) I had thus the satisfaction by the end of the season of having the completed portion of the Kattywar Survey in a more compact form that it has ever yet presented. It will be seen by reference to the Index Map that the topography now completed includes sheets V to IX, XII to XIX, and XXIII to XXX. This will enable degree sheets VI and VII to be prepared on a scale of 4 miles to the inch.

(12.) I am happy to say that in the ground we have been surveying during the past season nearly the whole of the Täalluka boundaries have been properly demarcated by the local committees appointed for the purpose, and that in the maps we shall send in this year there will be comparatively few "undemarcated" boundaries to disfigure them.

(13.) Whilst the filling in, of the topographical detail in sheets XXIII to XXV and in XXIX and XXX was progressing, Mr. McGill was carrying on the triangulation in the

north, over the ground to be surveyed topographically during the approaching field season. Sheet XXII had been triangulated in season 1870-71, and I had instructed Mr. McGill to endeavour to complete the triangulation of sheets X, XI, XX and XXI: this was finished by the end of the season.

(15.) During the approaching season nearly all hands will be employed on the topography of sheet XXII and of those sheets that have just been triangulated over by Mr. McGill, who will himself be employed in triangulating in the vicinity of Rájkot.

(16.) I have been in frequent consultation with Colonel W. W. Anderson, the Political Agent of Kattywar, as to the ground he would now wish taken up for survey, and he is anxious that I should commence operations in the vicinity of Rájkot, (the Head Quarters of the Political Agency) good maps of the country about which are very much wanted, that portion of the existing map of Kattywar being exceedingly unreliable. To show the urgent necessity that exists for a more reliable map of the country, than that which at present exists, I may mention 2 or 3 comparisons I have made between our work of the past season and the existing map, which was compiled in the Chief Engineer's Office, Bombay.

			Correct	According to existing map
Distance in miles between		Anandpur and Cholila	20¼	26
Ditto	ditto	Adkot and Panchaorda	3	7¾
Ditto	ditto	Babra and Jasdan	14	17
Ditto	ditto	Karasia and Jasdan	7	2½

(17.) Besides these linear inaccuracies the lines of watershed and drainage are in many instances entirely incorrect; so much so that for any engineering purposes, the old map may be considered as worse than useless. I recently had a visit in my office in Púna from the Agent of the Bombay *Baroda and Central India Railway, with reference to a proposed extension of their line from Wadwán (sheet XII), the present terminus of the Railway in Kattywar. An examination of the original maps of the past season induced him to lay out for detail survey altogether a different line to what he had originally intended.

(18.) I now proceed to report separately on the work of each Assistant. Lieutenant A. W. Baird, Assistant Superintendent joined the party in June, on return from sick leave in England, and has recently been appointed to the independent charge of a Party now being formed for the purpose of carrying on tidal and spirit leveling operations in Western India. During the few months that he has been attached to this office, Lieutenant Baird has been very regular in his attendance at office and has been of very great assistance, both in the ordinary computations and also in the reduction and arrangement of the traverse computations. We have now in the office a large mass of records connected with the Tálluka traverses and Lieutenant Baird has been indexing and arranging these in a methodical manner, a work which will save much time and trouble hereafter.

(19.) Mr. McGill left Gogo on the 9th November, but the great storm of the 12th which was felt nearly all over eastern Kattywar) was followed by a succession of storms more or less severe, during which a great quantity of rain fell, delaying very considerably all the Assistants on their march and making the journey to the interior a most unpleasant one, as the roads in Kattywar after heavy rain are all but impassable. These heavy showers continued up to the 20th and did a great deal of damage to the grain crops, then in course of collection, as also to the cut grass, a great quantity of which was ruined, and nearly all the remainder more or less damaged: cotton however was benefited by it, and perhaps on the whole it did as much good as harm, as the previous fall of rain had been very scant and the young crops of all kinds were much in want of moisture. Notwithstanding the rain Mr. McGill was able to commence his observations in sheet XII on the 20th November, and by dint of that hard and steady work on which I have more than once had the pleasure of reporting, completed the work allotted to him by the middle of April. Many of his stations of observation were old Tower Stations of the Kattywar and Guzrát Longitudinal Series and considerable difficulty was experienced, as in most cases the platform surrounding the paka central pillar had crumbled away; and as the greater number of these towers were from 20 to 40 feet in height it was a matter of no small trouble to erect wooden platforms to support the observatory tent, especially in a country where timber is very scarce and difficult to procure. Mr. McGill adopted a plan of sending to the headmen of all the surrounding villages receipts for ropes, bamboos, timber, &c. These receipts contained a promise to return all the stores when done with. By this means he used to collect in an hour or two material sufficient to construct his platform, which was erected in a few hours more at a cost of a few rupees, whilst had he not adopted this

expedient, he might have been delayed days at each station and spent a small fortune in the purchase of stores from the neighbouring towns of Dholera an Wadwán. It is rather a peculiarity of the district that men will often *lend* material when no amount of persuasion will induce them to sell.

(20.) This district triangulated over by Mr. McGill is almost a dead flat with very little detail and will prove easy ground for our Surveyors. It is, like the rest of Kattywar, divided into numerous petty states, the north-western portion is mostly the property of Dhrángdra one of the four first-class states of the country. I paid a visit to the "Ráj" as the chief of the State is called, during the cold weather and the Darbár Officials have always been very obliging and ready to help us as far as practicable, affording a marked contrast to the neighbouring state of Wadwán, which has obtained rather an unenviable reputation of an opposite kind.

(21.) The Dhrángdra Ráj is an enterprising and energetic man, and is pushing on of his own accord various works of improvement, such as the construction of roads, building of dharmsálás, planting out of trees, and in even helping forward the construction of a railway, which amongst other benefits will carry away to distant markets the excellent building stones of various kinds that are found in his territory, more especially to the north of the town of Dhrángdra where beautiful sandstone is procurable.

(22.) The other principal states in the District are Talsana, Rájpura, Lakhtar, Bajana and Patri. Portions also of the states of Limri and Wadwán enter into these sheets, which nearly all belong to the district of Kattywar called "Jhalawar" or country of the "Jhalas" a tribe of Rájpúts said to have settled down in these parts in about the 8th century. The original name of this tribe was "Mukwahana," a name said to be still existing in Central India. Several of the smaller states once formed a portion of Dhrángdra and although now actually entirely independent, their chiefs do not consider their investiture on succession to the crown complete until presented with a dress by the Dhrángdra Ráj.

(23.) With the exception of occasional low stony ridges bare of cultivation the country is entirely flat, and is on the whole fertile. The sandy soils produce bájri and jawári crops and the blacker soil which was once very famous for the quality and quantity of its wheat is now chiefly covered with cotton. The water of the district is not good, towards the Runn it is brackish and is mostly collected in tanks, a great many of which get dry in the hot weather following a bad monsoon, in which case wells are generally dug at the bottom of the tank. A more elaborate description of the country will be given after it has been topographically surveyed.

(24.) Mr. McGill in the course of the season's operations covered a space of 1760 square miles with 165 triangles, besides measuring 947 triangles (only 2 angles observed) for purposes of fixing points for our detail Surveyors. He observed from and fixed the heights of 103 stations, besides fixing the heights of 98 stations which he did not visit, altogether a first-rate season's work; other details connected with which will be found in the tabular statement attached to this report.

(25.) Mr. F. Ryall, who joined the Party during my absence on privilege leave in October, left for the field with the other Assistants at the end of that month. He had never had any previous experience in plane tabling, so I sent him to learn under Mr. Gwynne, one of my best trained hands. He was somewhat slow in picking up the work and remained with Mr. Gwynne until the end of December, when he commenced independent work. His progress was for some time very slow, but as the season advanced, he got on faster and at the close had completed 85 square miles of survey on the 2" scale. I am glad to say that his mapping was very carefully and accurately done. Mr. G. Anding rejoined the party from sick leave on the 1st of June, since which date he has been employed in miscellaneous computations under Mr. McGill.

(26.) Mr. J. Wood was transferred from the Astronomical to the Kattywar Party shortly before we took the field. He had no prior experience in the work of a topographical party, but he practised with a plane table in the neighbourhood of Púna before leaving for the districts. He also, during the latter half of November, worked with Mr. Gwynne preparatory to commencing independent work. During the season he completed 114 miles of detail survey. His out-turn would have been greater, but there was a good deal of detail in the ground he had to survey; besides which I made him constantly change boards with a young Native Surveyor (Nilkant) who was out in the field for the first time and whom it was necessary to train in habits of accuracy, which I thought would best be done by constantly checking his work by an accurate and careful Surveyor, such as Mr. Wood has proved himself to be. This assistant has been very regular in his attendance in office and has been of much use both in the computations and mapping.

(27.) Mr. Gwynne surveyed during the season 161 square miles. This is not so large as his usual out-turn, but most of the ground he worked over was hilly and full of detail; besides which he was in the early part of the season considerably delayed by having to instruct Mr. Ryall and one of the Native Surveyors in the theory and practice of plane tabling. The ground surveyed by Mr. Gwynne is as usual well and truthfully delineated. In recess Mr. Gwynne has been most useful: his skill and experience in preparing the maps coupled with his steady application to work makes him a valuable assistant in the office.

(28.) Mr. T. Rendell worked well in the field, completing the survey of 216 Square miles, part of which was intricate and with a good deal of detail. His work is accurate and neatly executed. In office, since return to Head Quarters Mr. Rendell has done good service in looking after the reduction of the traverses, although I regret to say that illness has somewhat interfered with his regular attendance in office.

(29.) There is a great deal of labour now incurred in the reduction of our Täalluka traverses, the calculations and plotting of which occupy the time of about four assistants during the whole recess, and as unfortunately some of the men who execute the traverses are not sufficiently educated to be entrusted with the computations, a great deal of extra labour is thrown on to the hands of those who would otherwise be employed in the ordinary routine work of the office. This would indicate the necessity of refusing to entertain in future as Native Surveyors candidates who have not sufficient knowledge of English and of elementary mathematics to enable them to compute out their own traverses.

(30.) Although the system now adopted of computing out by rectangular co-ordinates all our traverses, causes great additional labour yet it is no doubt more than compensated for in the increased value of the results, as our traverses can now be plotted at any time on any desired scale and will be of great use in future surveys for revenue purposes.

(31.) Mr. E. N. Wyatt has, as usual, done a first-rate season's work, viz., triangulated over 140 square miles of country, computed out his triangles in the field and surveyed topographically on the 2" scale 215 square miles (in sheets XXIX and XXX) of country, parts of which were very hilly and intricate. Besides this he has run 41 miles of traverse along Täalluka boundaries.

(32.) As before explained there was a quantity of unfinished work, both triangulation, detail Survey and traversing to be finished in sheets XXIX and XXX before those sheets could be got ready for publication. It was a very hard season's work to get through, and I selected Mr. Wyatt for the purpose knowing that he, if anybody, would accomplish it. I am glad to say it was completed to my entire satisfaction, although I much regret that Mr. Wyatt has since suffered severely in health from his exertions in the field. Details regarding Mr. Wyatt's triangulation will be found in the "Tabular Statement." Considering that it was his first attempt at triangulation, the results may be pronounced good. His traverses however have a rather larger error than most of those executed by other Surveyors during the past season. This is probably owing to his not having the same opportunities of testing the length of his measuring chains as those Surveyors who were working near my own camp. His errors were nearly always in deficiency.

(33.) Mr. Wyatt only returned to Head Quarters late in May and on the 1st July left Púna on three months privilege leave.

(34.) Mr. W. Fielding has turned out 219 square miles of detail survey in a very creditable manner and would have done more but that I kept constantly changing boards with some of the junior Surveyors a process which, though decreasing materially the out-turn of work, adds very much to its value.

(35.) Mr. Fielding worked steadily and zealously throughout the season and continues to give every satisfaction. He also has been granted three months privilege leave which he availed himself of on the 1st of August.

(36.) Of the Native Surveyors Vissaji Ragonáth has been very useful in the field in preparing and projecting plane tables, in occasional computations, in giving out traverses and other miscellaneous work. In Púna he has been mostly employed in the traverse computations.

(37.) Govindji Mahálay surveyed 260 square miles of country in very creditable style and has worked hard and steadily in office in plotting traverses, &c.

(38.) Vishnu Moreshwar surveyed 222 square miles in good style and though frequently sick has been usefully employed in office in tracing, drawing, &c.

(39.) Ráoji Naráyan and Shrídhar Saccarám surveyed 174 and 258 square miles respectively. Both these Surveyors, especially the latter, have much improved both as regards quality and quantity of their work; although in their anxiety for a creditable out-turn they are occasionally apt to hurry too much over their ground.

(40.) Nílkant Vittal, brother of Shrídhar Saccarám and a new hand this season, completed 82 square miles of country and bids fair to become a good Surveyor.

(41.) Of the Traverse Surveyors, Nursu Dinkar, Krishna Govind and Bolúji Bhosaker completed respectively 299, 170 and 270 miles of boundary traverse and the two latter in addition traversed 75 and 81 miles respectively of check lines. The traverses this season will stand very favorable comparison with those of former years. They have all been computed out and corrections applied from the true geodetical distances.

(44.) Owing to the large out-turn of field work during the past two seasons and the amount of work involved in the traverse computations as well as the absence from sickness of many of the Assistants, our computations and mapping are somewhat in arrears, but I hope, before the close of the recess, to be able to send to Head Quarters for publication fair copies of all our last season's maps.

(45.) The country under detail survey by Mr. Wyatt in sheets XXX and XXXI has been described in former reports. The Northern part of his work forms the Southern portion of the Gir Range of mountains, one of the few places in India still forming the haunt of the Lion.

(46.) I have on many occasions during the past few years, while passing through the Gir, tried hard to shoot one of these animals, but I have never been rewarded by success until the present year, when accompanied by Mr. Wyatt, who was surveying in the neighbourhood, we had the good fortune to bag two full grown ones and two cubs. As I do not know of any naturalist or sportsman (Dr. Jerdon not excepted) who has written any account of the habits of the Lion, a few details may not be uninteresting. It is erroneous to suppose that the Kattywar (Guzrát) Lion is mancless, although in the specimens I have seen, the mane has been considerably shorter and of lighter colour than that of the African species. One that I shot, supposed to have been eight years old from its containing that number of lobes in its liver, had the hair covering the back of the head and neck not more than a few inches long. The dimensions of this animal taken as it lay dead on the ground were as follows :—

Length from nose to tip of tail	8′	10″
„ of head and body alone	5′	11″
„ of tail	2′	11″
Height at shoulder	3′	4″
Girth of Neck	2′	6″
„ Chest	4′	1″
„ Fore-arm	1′	9″
Length of hair on mane		5″

(47.) In appearance its colour is very much like that of a camel or a female nílgáe, and I have on one occasion when at a distance actually mistaken a lion for the latter animal. From its colour it derived the name, by which it is known in most parts of Guzrát, "Untía-Bág" or "Camel coloured Tiger." In the Gir however it is always called "Sáwaj," a name that I do not think is known out of Kattywar. The male is rather darker than the female and is a little heavier about the head and shoulders; the female being very much the same shape as the common tiger. Their habits are somewhat similar to those of the tiger. They always travel at night leaving their daily resting place about sunset. Their first visit is generally to the water, after which they wander about in search of food, often going many miles over hill and dale in their nightly peregrinations. In passing from one favorite resting place to another they generally make use of the best roads the country affords, and I have often met their foot-marks going for miles along the road I have been myself traversing; and if one did happen to travel in that country on a fine moonlight night, I can imagine nothing more likely to occur than a chance rencontre with one of these forest kings. They feed chiefly on nílgáe, sámbar and wild hog, a single blow of their paw generally sufficing to break the back of the largest animal. They sometimes commit considerable depredations on the herds of buffaloes that are taken into the Gir for grazing. Owing to the great heat, the cattle are generally allowed to wallow in the mud and lie under trees during the hottest part of the day; and at night they are driven out to graze. As a rule they keep together, in which case they are never disturbed by the Lion; but if by chance a sick one should lag behind or should any wander away to a distance from the rest of the herd, the Lion, if there be one near, is sure to bag it, however big and powerful it may be. As long as the herd keeps together, however, there is no fear, as the Lion dare not attack. If the kill be made early in the evening and the lion be hungry, he will at once

TABULAR STATEMENT OF OUT-TURN OF WORK IN KATTYWAR DURING THE FIELD SEASON 1871-72.

Triangulation.

No.	Observers' Names.	Instrument used.	Area triangulated.	No. of Points Heights fixed.	No. of Points Position fixed.	No. of stations visited.	Triangles 3 Angles observed.			Triangles 2 Angles observed.	
							No. of triangles.	Mean triangular error.	Discrepancy per mile.	No. of triangles.	Average Discrepancy per mile.
			Sq: miles					"	feet		feet
1	Mr. J. McGill, ...	Cooke and Sons' 7" No. 1-56.	1760	201	657	103	165	11·9	0·5	947	1·5
2	„ E. N. Wyatt, ...	Tr. & Simms' 6" „ 709.	140	20	82	19	23	18·4	0·8	100	1·6
		Total	1900	221	739	122	188	Mean 15·15	Mean 0·65	1047	Mean 1·55

Topography.

No.	Plane Tabling.	Area surveyed Scale 2 inches = 1 mile.	Average No. of plane table stations per mile.	Remarks.
		Sq: miles		
1	Mr. F. Ryall, ...	85	11·3	
2	„ J. Wood, ...	114	18·9	
3	„ N. Gwynne, ...	161	9·1	
4	„ T. Rendell, ...	216	7·4	
5	„ E. N. Wyatt, ...	215	6·4	
6	„ *W. Fielding, ...	219	8·9	
	Native Surveyors.			
1	Govindji Mahalay, ...	260	8·0	
2	Vishnu Moreshwar, ...	223	10·4	
3	Rãoji Narayan,...	174	8·5	
4	Shridhar Saccarãm, ...	258	10·6	
5	Nilkant Vittal, ...	82	13·5	
	Total ...	2036	10·3	

Traverses.

Names.	No. of Linear miles traversed.		Remarks.
	Tãaluka Boundary.	Check Lines.	
Mr. E. N. Wyatt, ...	41·2	.....	Average error in traverse work per 1000 links
Nursu Dinkar,...	299·4	... ...	Mr. Wyatt, 1·77 links
Krishna Govind, ...	169·8	74·8	Nursu Dinkar, 0·84 „
Bolúji Bhosaker, ...	269·0	81·1	Krishna Govind, 0·48 „
			Bolúji Bhosaker, 0·75 „
	779·4	155·9	

commence eating it, but will always leave it about daylight and go and rest for the day at some secluded spot in the neighbourhood, either down near the water in the shade of Caranda and other trees, or, what is perhaps more common, they will go on the top of some neighbouring hill where they may get a cool breeze and where they lie out in the open under the shade of a big stone or, when procurable, of a large banyan tree. When disturbed they do not slink away like a tiger or panther, but walk or run upright without any attempt at concealment. Being very nearly the same colour as the ground and of the scorched leafless trees with which these hills are covered in the hot weather, it is very difficult to see them before being seen oneself; and this generally happens, owing to the frequent absence of undergrowth in these jungles before the sportsman gets within range.

(48.) I have never heard an authentic instance of an unwounded lion attacking a man, but when wounded, I should say that their ferocity would fully equal that of the tiger. It is a curious fact that not a tiger or a bear exists in a wild state in the whole of Kattywar. Panthers however are very numerous in the Gir as well as in other parts of the country.

(49.) As far as I know from my own experience and from enquiries I have made, I am of opinion that there are not more than fifty lions in the whole country. The female generally has two cubs, but probably, as is the case with other animals of the kind, there are three born—it being supposed that the first born is always devoured by the mother.

(50.) The country surveyed topographically in sheets XXIII, XXIV and XXV has also been described in last year's report. A fuller description will be given when the general report on the degree sheet is prepared.

(51.) Late in the season, after inspecting Mr. Wyatt's work, I went down to the south and examined very carefully the whole coast line between Diu and Verawal with the object of selecting stations for tidal observations. There is a place near Diu, to the N. E. of the island, which I think would be very well adapted for the purpose. It is the spot where observations were taken by Mr. D'Costa under Colonel Nasmyth's superintendence in 1855. There is a low deep channel to the W. of the island of Diu, just opposite the town of Brancavara, which for some reasons would be more suitable, but which would not be so well protected during the S. W. monsoons. From this place up to and beyond Verawal there is no suitable spot. There are many creeks which might at first sight look promising, but a little investigation always brings to light the existence of a bar with a little or no water over it at low springs. I have communicated the result of my investigations to Lieutenant Baird who has now been entrusted with the carrying out of the proposed tidal observations. I applied to the Bombay Government for the loan of a steamer or other vessel, to enable me to make a more extensive examination of the coast line, but competent authorities decided that it would be too dangerous a trip to undertake so late in the season; and I was obliged to content myself with the examination of a comparatively small strip of coast. I hope however that arrangements will be made to enable Lieutenant Baird to carry out a very complete survey of the coast during the approaching cold whether; so that, on the arrival of the new instruments now being constructed in England under Colonel Walker's superintendence, it is to be hoped the tidal observations on this side of India may fairly be started.

(52.) The total expenditure on the Party during the past financial year has been Rupees 68,830, against 66,859 of the previous year, whilst the out-turn of work finally completed is 2,036 square miles, against 2,064 of the former year. Deducting Rs. 3,600, the cost of the Boundary Survey Establishment, we have an average expenditure per square mile of mapping completed of Rs. 32-0-7, against Rs. 30-10-4 of 1870-71 and Rs. 58-9 of 1869-70.

(53.) It is again a pleasure for me to be able to acknowledge the cordial assistance we always receive from Colonel W. W. Anderson the Political Agent and the Assistants under his orders. The country is in a somewhat disturbed state, the police arrangements being very inefficient, owing to the enormous number of petty states into which the country is sub-divid d; but although there have been bands of mounted and well armed robbers traversing the country, against whom I have been more than once warned by the Political Assistants, I am happy to say that in no instance have they interfered with or annoyed either myself or any of our Survey Parties, although villages have been attacked and looted within a few miles of where my assistants have been working. The large tracts of wild hilly ground existing in the Gir and other places in Kattywar, afford admirable places of refuge for these bands, when the plains become too hot to hold them.

Extract from the Narrative Report—dated 29th August 1872—of Lieutenant J. HILL, R.E., Assistant Superintendent 1st Grade G. T. Survey, in charge * Kumaon and * Gurhwal Party.

(1.) When the skeleton sheets of the large scale survey of Masúri and Landaur were completed, a reduction by photography was made from them at the Head Quarters' Office to serve as a guide map for Masúri and Landaur. Three of those sheets, which include the most important part of the sanatarium, were published in the summer of 1867, and the guide map was published in April 1871. During that interval of four years several houses had been built, and other changes made, and the above-mentioned reduction was only published so as to be a convenience to the public until a more perfect guide map could be prepared.

The Recess of 1871.

Guide Map for Masúri and Landaur. Second Edition.

(2.) On the return of the party to Masúri in the last week of April 1871, the preparation of a second edition of the guide map was commenced, on the basis of the reduction mentioned in the preceding paragraph. This second edition contains all the changes that have taken place in the sanatarium since the preparation of the original maps. It is furnished with a table of distances, and an index, and a number of new barometric heights are also entered in it. The measurements for the table of distances were made by Mr. J. Low with a perambulator of Sir A. S. Waugh's pattern, and in addition to them some distances were extracted from a table prepared by Mr. J. B. N. Hennessey several years ago, and kindly placed at my disposal by him. The new houses which had been built, and the other changes which had taken place in Masúri and Landaur were laid down by Messrs. J. Peyton and T. Kinney on the original large scale maps, and afterwards entered in the guide map by the latter officer, who assisted greatly in the general preparation of the map. Mr. H. Todd took the barometric height observations with an aneriod barometer of 4½ inches diameter. A similar stationary instrument was read in my office at intervals of half an hour during the time he was engaged on this duty, and the curve of atmospheric pressure indicated by it was used to correct the readings of the transported barometer: the results thus obtained have proved very satisfactory. On the completion of the map in September 1871 it was sent to the Head Quarters office at Dehra Dun, and there published.

Kosi Valley Survey Maps.

(3.) The main work of the recess was the preparation of the fair maps of the Kosi Valley Survey, which comprise 8 large shaded sheets, and the same number of skeleton charts. The preparation of those maps was a work of time, for they were intended to enable an Engineer to measure the slope of the ground at any particular spot in the survey, and to attain that object it was necessary to adopt a rather laborious method of shading, as explained in my last year's Narrative Report, and the shading was effected by the interpolation of horizontal lines according to a scale of shade which gave a vertical interval of about 15 feet between the *hachures*. In the skeleton charts the hill shading was omitted, but the dotted contour lines were retained.

Survey of the higher ranges of the Himalayas.

(5.) The field work began with the extension of the triangulation in the higher mountain ranges of Gurhwal, Messrs. J. Low and L. Pocock were selected to perform it. Their work consisted in extending, as far as the limited time available would permit, the two minor series of traingles on which they had been engaged in 1869. Mr. Low extended his series up the Mána valley from the temple of Badrináth to the village of Ghastoli, and fixed a sufficient number of points to enable the topographers to finish the survey of the valley; and Mr. Pocock was able to complete thoroughly the triangulation of the Níti valley from the village of Kargúti to the Niti Pass. The details of their work are included in the tabular statement on page 45—a.

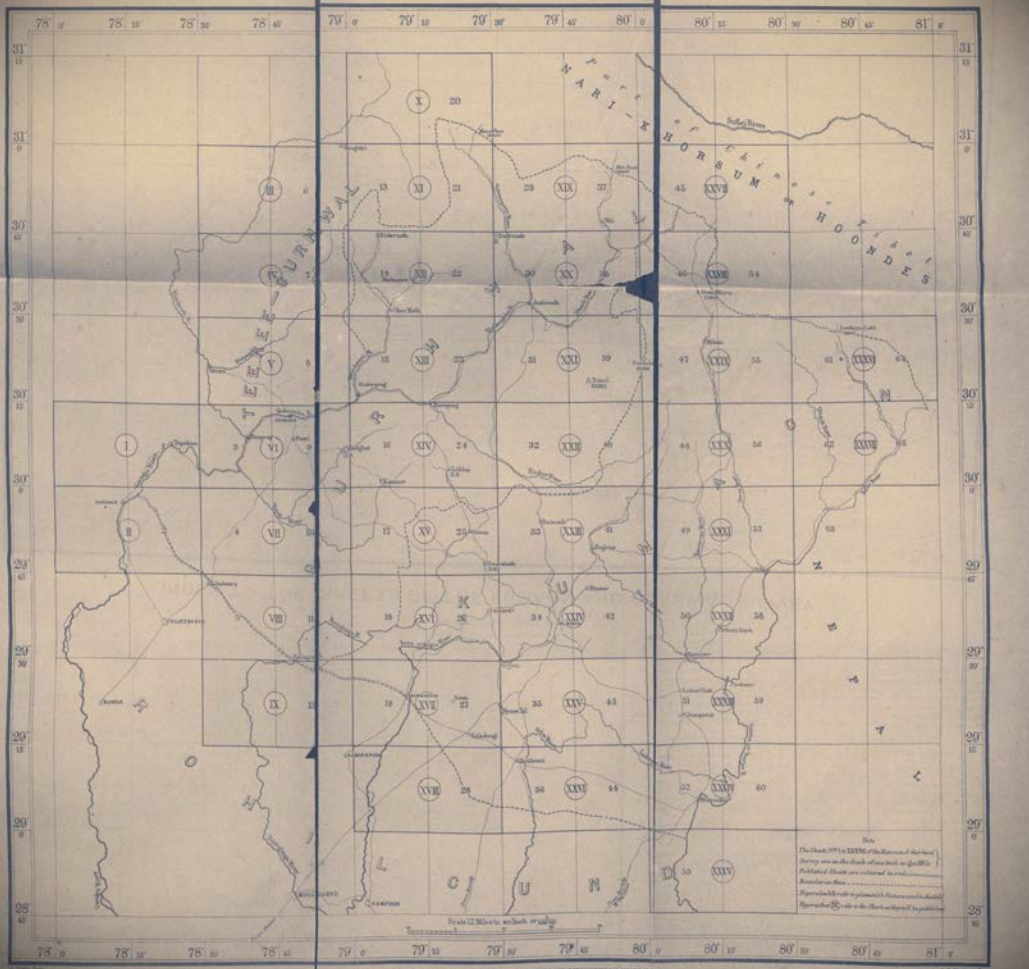
Trans-Sutlej Peaks.

(6.) On reaching the Níti Pass, Mr. Pocock chose three stations on the watershed (all of them just over 17,000 feet above the level of the sea) from which he was able to fix the positions of 8 remarkable peaks beyond the *Sutlej. One is the famous Kailás Parbat, the most commanding peak visible from the Níti Pass; another is a peak about 7 miles to the north of the Choka La, laid down as Sápju by Mr. Pocock.

(7.) The difficulties to be overcome in carrying a triangulation over such valleys as those of the Mána and Níti are by no means insignificant. Both those valleys are enclosed by mountain ranges the average height of whose peaks is considerably over 21,000 feet above the level of the sea, and the spurs are as lofty as the ranges from which they spring, until they come within a few miles of the main watercourses of the valleys. The valleys present the appearance of narrow gorges overhung by stupendous and inaccessible precipices, and it is obvious that in such ground a triangulator has little or no choice as to the shape of his figures, but has in many cases to content himself with observing from any commanding point on which he may be able to set up his in-

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

INDEX TO THE SHEETS OF THE KUMAON AND GURHWAL SURVEY



Compiled under the direction of Major T. G. Montgomerie, R.E. 1870. Great Trigonometrical Survey of India.

Photozincographed at the Office of the Superintendent Great Trigonometrical Survey, Calcutta, September 1870.

DETAILS OF TRIANGULATION, KUMAON AND GURHWAL PARTY. SEASON 1871-72.

NAMES.	Area in square miles.	1st Class Secondary Triangles.	2nd Class Secondary Triangles.	Stations visited.	Intersected points.	Trigonometrical heights.	Barometric height observations.	Points whose Elements have been computed.	Average Area in square miles to each Point.	Average Area in square miles to each height.	Number of Boundary Pillars fixed.	REMARKS.
Lieut. H. M. Chambers, R.E., ...	240	18	101	19	59	70	...	...	3·1	3·4	...	Lower mountain districts near Naini-Tal.
Mr. E. C. Ryall, ...	660	33	280	27	151	93	...	...	3·7	7·1	...	Forest-clad Bhábar hills.
„ J. Low, ...	150	10	58	11	31	42	11	...	3·6	3·6	...	Higher mountain ranges of Gurhwal.
„ L. Pocock, ...	340	14	49	15	26	41	25	...	5·3	5·3	...	Higher mountain ranges of Gurhwal.
	130	0	12	14	0	12	...	...	10·9	10·9	15	Bhábar district.
	302	...	14	...	8	8	...	...	...	...	...	Trans-Sutlej peaks.
„ T. Kinney, ...	40	5	32	10	27	21	...	...	1·1	2·0	...	Forest-clad Bhábar hills.
Total, ...	1862	80	546	96	302	287	36	533	4·0	5·6	15	

Topographical Details.

NAMES.	Area surveyed in square miles.	Plane Table stations.	Average No. of Plain stations per square mile.	Number of square miles under cultivation.	REMARKS.
Mr. E. C. Ryall, ...	38	243	6·4	0	Chándípahár wooded hills of a height varying from 1,000 to 2,000 feet above sea-level.
„ J. Peyton, ...	*263	475	1·8	33	Chiefly forest ground of a height varying from 2,500 to 8,100 feet above sea-level.
„ J. Low, ...	*338	763	2·3	41	Chiefly forest ground of a height varying from 3,000 to 9,000 feet above sea-level.
„ L. Pocock, ...	219	385	1·8	13	Chiefly forest ground of a height varying from 770 to 7,100 feet above sea-level.
„ H. Todd, ...	248	446	1·8	24	Chiefly forest ground of a height varying from 3,500 to 9,000 feet above sea-level.
„ E. Litchfield, ...	173	503	2·9	16	Chiefly forest ground of a height varying from 2,500 to 7,700 feet above sea-level.
Total, ...	1279	2815	2·2	127	* These areas are exclusive of 93 square miles of the Nepál border sketched from Kumaon.

trument. To the physical difficulties he has to encounter must be added the difficulties of obtaining carriage, supplies, and fuel. In these ranges the forest line ceases at an altitude of about 11,000 feet above sea level. Up to an elevation of 14,000 feet firewood is carried up from the forests and stacked for use; but above that elevation the Surveyors are dependent for fuel on the root of a small wild plant which is found at elevations of 13,000 feet and upwards, and the task of collecting a sufficient quantity of this root is one of great labour. There being very little cultivation in these regions, the inhabitants descend during the month of October to the lower districts of Kumaon and Gurhwal and barter their salt for grain which they carry back to their homes in the mountains. In order that Messrs. Low & Pocock might carry on their work successfully, they had to look to the civil authorities for assistance. This was given them most effectually by Captain Garstin the Senior Assistant Commissioner of Gurhwal. He arranged for their supplies, their carriage, and their fuel, and, as in former years, did every thing in his power to help on the progress of the survey.

The Field Season of 1871-72.

(8.) The chief work of the field season consisted in completing the triangulation of both the country to the east of Naini-Tal and the Bhábar tracts between Haldwáni and Bharmdeo, and in surveying topographically the districts round Baiznáth, Bageswar, Lohághát, Pitorágarh, and a part of the Bhábar to the south of Káli Dungi, all of which are within the district of Kumaon. It was also thought necessary to triangulate and sketch some ground opposite Hardwar where the low sandstone hills on the left bank of the *Ganges extend for a short distance beyond the boundary of Gurhwal, and terminate in the plains to the north of Asafgarh.

(9.) The triangulation was apportioned to Lieutenant H. M. Chambers R. E., and Messrs. E. C. Ryall, L. Pocock, and T. Kinney, and the topography to Messrs. E. C. Ryall, J. Peyton, J. Low, L. Pocock, H. Todd and E. Litchfield.

(10.) I shall confine myself to the general character of the work done. Its details are to be found in the tabular statement on the preceding page.

Lieutenant H.M. Chambers, R.E.

(11.) Lieutenant Chambers was employed in my camp familiarising himself with the use of a 12-inch theodolite, till the beginning of the new year. During that time the ground allotted to him for triangulation was being staved. It lies to the east of Naini-Tal, and is of a height varying from about 1,500 to 7,500 feet above sea-level. It is chiefly remarkable for a cluster of small lakes grouped together in the neighbourhood of Bhím-Tal. In other respects it is like ground of a similar altitude in other parts of Kumaon, such as has been described in former reports.

Triangulation east of Naini-Tal.

(12.) During the winter months the people of this district leave it to cultivate their fields in the Bhábar. Carriage could not, therefore, be obtained on the spot, and it became necessary to hire permanent coolies from other districts to enable Lieutenant Chambers to carry on his work.

(13.) There was then a considerable quantity of snow on the higher ground, and it chanced most unfortunately that while Lieutenant Chambers was crossing a snow-drift on the 11th January he fell and sustained a fracture of the collar bone. This accident obliged him to take sick leave, and he was not permitted by the Surgeon who attended him to resume work until the 25th February. He succeeded, however, by making great exertions, in finishing his triangulation by the end of the field season; and the results of his work, as since tested by computation, have proved very satisfactory.

Mr. E. C. Ryall. Survey of Chándípahár.

(14.) Mr. Ryall was employed on the triangulation (including its computation,) and the sketching of the hill tract of Chándípahár opposite Hardwar mentioned in para: (8.) In intricacy this piece of ground is unequalled by any part of Kumaon or Gurhwal. Its survey, which was a matter of no little labour, I found, on inspection, to be thoroughly well done.

(15.) Mr. Ryall has furnished the following notes descriptive of the Chándípahár hills.

"The Chándípahár portion of the Sewáliks, in the Bijnaur District, is bounded on the West by the river Ganges and on the South-East by the Paili Rau up to its junction with the Khara Sot: from thence the boundary runs up the Khara Sot about 2½ miles, turns up into a small tributary in a North-westerly direction, crosses a low ridge and goes into the Ghasíram ka Sot, continuing along this Sot till its junction with the Ganges.

"The whole of this tract of country is densely covered with forest. The Northern slopes of the hills are principally clad with Sál trees. The Southern sides of the hills are generally rugged, and are consequently almost entirely deserted by Sál trees. The bottom of the hills is densely covered with bamboos, which contribute a good deal to the revenue, giving employment to scores of bamboo cutters.

"It appears that owing to the great demand for charcoal in the Rúrki Workshops, the Chándípahár hills have been made over entirely to the Superintendent of the Rúrki Workshops, who leases out certain tracts of forests to charcoal burners.

"The formation of the hills is chiefly of sandstone, identical with that of the Sewáliks of Dehra Dun. The whole formation is so very much broken up that it presents a sea of confusion, and renders the tracing out of the different little spurs, knolls and streams (which are almost alike one another) a matter of great difficulty."

Repair of Chándípahár H. S.

(16.) The Principal Hill Station of Chándípahár (which belongs to the Great Arc Series) having fallen out of repair, instructions were received to undertake its restoration. As Mr. Ryall was on the spot I entrusted this work to him, and he commenced upon it as soon as he had finished his survey of the contiguous hills. The slipping away of the whole of the Southern half of the original platform caused a great deal of damage to the side of the hill below the station, and it was only after cutting down for about 22 feet that Mr. Ryall found ground firm enough for a foundation. He completed the repair of the station in 10 days, and then started to take up the work assigned to him in Kumaon.

Bhábar Triangulation.

(17.) Mr. Ryall's work in Kumaon consisted in completing the triangulation of the Bhábar hills which extend from Haldwáni eastward to Bharmdeo. These hills are even more densely covered with forest than those to the West of Haldwáni, and the ground in general is somewhat intricate in character: carriage, also, is not to be procured without considerable difficu ty. In spite of these drawbacks Mr. Ryall was able to finish his triangulation, and at the same time a most excellent season's work, by the second week in April.

Mr. J. Peyton.

Topography of the district round Pítorágarh.

(18.) Mr. Peyton was employed in the Pítorágarh district. From its eastern margin above the river Káli he was able to sketch 48 square miles of the Nepál border. The part of Nepál so sketched seems to be of a bolder and more rugged character than the country opposite to it in Kumaon. Mr. Peyton closed work in the last week in April. Before he did so, I inspected his ground and found it, as usual, faithfully and artistically delineated.

(19.) Mr. Peyton gives the following particulars regarding the district he surveyed.

"The Pítorágarh district is highly cultivated; but a great many of the villages, especially those near the Káli river, are surrounded by dense belts of jungle, the Chír pine being the predominating tree. The Dhaj mountain on the north throws out very thickly wooded spurs in the direction of the Káli, with a very gradual descent for about 6 miles, and then an abrupt fall, with steep precipitous ground, on the edge of the river. This appears to be a remarkable feature of nearly all the ridges, which rise precipitously from the river, and then slope up very gradually to the main range which forms the watershed of the Káli and Rámganga. The Askot district north of Dhaj is traversed by a large tributary of the Káli, called Charma Gadh, and has a good deal of undulating ground, all under cultivation, the villagers being chiefly Dótiáls from Nepál, who have been compelled by the high rate of land assessment to leave the Maháráját's territory and settle in Kumaon; and all the productive land on the banks of the Káli is is now in their possession, the Chír forest being extensively cleared, and villages rising on all sides, with broad green belts of cultivation, forming a most pleasing relief to the sombre monotony of the forest. So rapidly is the work of reclaiming forest going on, that probably in a few years very little jungle will be left; in fact only in such places as are rendered inaccessible by huge precipices.

"The rock and general formation is limestone, but here and there a crumbling kind of sandstone is predominant, especially in the lower spurs overhanging the Káli.

"The roads, both Government and village, are generally steep in this part of Kumaon. Besides the great main road to Almora, which has a very steep gradient on both banks of the Rámganga and Sarju, there is a tolerably good road to the higher districts on the north, much used by traders from Thibet, who bring large flocks of sheep laden with borax, which they sell in large quantities at Rámnagar, Bharmdeo, and other places at the foot of the hills. There is a very fair road from Pítorágarh to Julaghát, easily passable for mounted travellers and laden cattle, about 12 miles in all, or easy two marches by halting half way at the village of Munakot. Leaving Kumaon by the suspension bridge at Julaghát, that road rises by a sharp zig-zag for about a mile, and then running along the crest of a high range with a gentle ascent, leads to the Fort of Baitharri in Nepál. There are also some good village paths leading about the higher ranges in Askot. The custom of the villagers being to establish cattle sheds on all the open plateaux and easy ground, it follows that fair paths will be found running along most of the great ranges. Besides the main road to Almora, there is a circuitous road *vid* Thal, and Bageswar, which is much used during the time when fairs are held at both places, in February at Bageswar, and in May at Thal.

"In the Pítorágarh district, wheat and rice are the great staples of production.

Mr. J. Low.—Topography of ground round Bageswar, and in Káli Kumaon.

(20.) Mr. Low closed work in the Mána Valley on the 5th November, and started for Kumaon to take up the sketching of the ground in the neighbourhood of Bageswar. He reached Bageswar and commenced his work there on the 19th of the same month. The country to the north of Bageswar on the right bank of the river Sarju he found to be the most difficult to sketch. The hills are there precipitous, lofty, and covered with dense forest. The rest of his ground presented few difficulties. It contains here and there a considerable amount of forest, but in general it is open, well cultivated, and dotted with numerous villages. He finished his work in this district by the beginning of April, and then marched into Káli Kumaon to sketch the part of the frontier which lies immediately to the north and south of the junction of the Sarju and Káli rivers. In addition to surveying this piece of country he was able to sketch 45 square miles of the Nepál frontier which were visible from his ground. On inspecting his work, I found it to be well and carefully done, and to exhibit a marked improvement on the last work he turned out on the same scale in 1869. He closed work for the season at the end of the first week in May.

(21.) The following are Mr. Low's notes on the part of the country he surveyed.

"The most remarkable place in the portion of country sketched by me is the town of Bageswar, celebrated for its Bazar, Temple, and two large fairs, the first and larger held in the latter end of January, and the second and smaller in February or March. The fairs are partly sacred festivals held in honour of the deity Bagnáth, to which flock devotees, pleasure seekers, and traders from the surrounding *patties*, and from Thibetan Tartary. Trade transactions also take place to a large extent, it being the emporium for all the surrounding country. The articles offered consist of the household property in common use, besides cloth, wearing apparel, skins, salt, borax, Thibetan ponies, and cattle from Gurhwal and the Chamba states. The Thibetan ponies being in greatr equest at the civil stations of Almora, Ránikhet, and Naini-Tal, fetch very large prices. Regarding the other articles of merchandise; salt, borax, and skins from the interior of Thibet form the principal staples of trade; the transport of the two former being effected by means of sheep and goats, which, on account of the rugged nature of the hills, afford the simplest and easiest method of carriage. In consequence of the utility of these animals to the traders large prices are offered, and it is not an unusual thing for Rs. 6-8 or Rs. 7 to be given for a good Chamba goat, which goats are always in consequence of their size and strength taken in preference to the sheep and goats of other districts. Salt is only procurable here at Bageswar, unless it be in the plains at Rámnagar many marches away. Regarding the borax; as Thibet is the only place in the east from which it is to be had, it can be readily understood that the trade in it is very great. Several thousand maunds of this article pass through Bageswar every year.

"The principal river is the Sarju, which is joined at Bageswar by the Gumti. Its banks during the rainy season are very malarious, but in the winter they are the resort of cattle dealers as they afford luxurious pasturage.

"Of the roads, the chief one running by the right bank of the Sarju may be considered the high way, being the one by which the traffic of Thibet is transported. After reaching Bageswar it is joined by those coming from Sameswar, Katur, and Sanodar, the Katur road being used by travellers from Gurhwal, the Sameswar by those travelling from Ránikhet and Háwal bágh. These roads are in excellent preservation.

"In the Karaihi *patti*, in this district, are a few iron mines worked only to an extent to suit the requirements of the neighbouring *patties*. They are worked by Domes, or the lowest class of people in Kumaon and Gurhwal, who prefer using only the bark of the Chír pine for smelting purposes as it burns with great intensity and emits no smoke.

"The ground I surveyed topographically in Káli Kumaon is well cultivated. The spurs of the hills run down into the large streams in a very precipitous manner, and the cultivated parts are therefore to be found in the more elevated portions of the spurs and ridges.

"From Tamli (a group of villages in Talla Des) there is a newly cut road about 3 feet wide leading to Lohághát. The road from Lohághát *viâ* Pacheswar, to Pitorágarh, which was formerly a regular made road, is now only a footpath, and this footpath is now scarcely traceable when it passes through cultivation.

"There are ferries over the Sarju at Khet Patoli and Dálifálma, near Pacheswar. To cross the Káli into Nepál rafts floated on dried pumpkin shells are made use of; another method is to cross by swimming, the swimmer being aided by a couple of these shells tied together, on which he rests his chest."

Mr. L. Pocock.—Topography in the Bhábar and Káli Kumaon.

(22.) On completing the triangulation of the Niti valley, Mr. Pocock marched south to take up his work in the Bhábar. The portion of ground allotted to him there lies near Káli Dungi, to its south, and is thickly covered with forest except in those spots where clearances have been made for cultivation. It is also quite flat, and it had therefore to be surveyed principally by the method of traversing. Before commencing the topography of this tract, it was necessary for Mr. Pocock to fix a few trigonometrical

points to serve as checks on his traverses. This he did by observing both from the points themselves and from trigonometrical stations on the low hills near Káli Dungi which command his ground; and he also computed out in the field the points (12 in number) he thus determined. He finished his Bhábar work by the end of February and started to take up the sketching of the country south of Lohághát in Káli Kumaon. He closed his work for the season on the 15th April, and I found it, on inspection, very carefully and accurately done.

(23.) Mr. Pocock has furnished the following notes on the ground he surveyed.

"The first portion of the ground surveyed by me lies between longs. 79° 15′ and 79° 30′. It is bounded on the South by the fiscal boundary of the Tarái, and on the North by latitude 29° 15′ which is about three miles from the foot of the hills. Except such parts as are cultivated, the ground is densely covered over with large forest trees. The Sissu, growing over the sides of the large open ravines is the only large tree of any value. The Khair (catechu) grows every where in close neighbourhood with the Sissu: this tree is much used by catechu dealers. The Sissu in former days, owing to its great value, was used most recklessly by the people of the neighbouring districts, and owing to the slow growth of this tree, the last 16 or 17 years of conserving the forest have not been sufficient to produce any large Sissu trees. Besides the many trees to be met with, there are large undergrowths of plants and creepers; more especially down in the Tarái portions where the cane grows in great abundance. The Tarái is a most difficult tract to traverse over, owing to the many swamps that intersect it. Without guides it is almost impossible to go through it.

"The part of the road from Murádabad to Káli Dungi which passes through this work is in fine order. No hackeries are permitted to travel on the metalled portion. The other roads are in good order during the winter and spring months. During the rains they are very little used, and not kept in repair, and the grass grows on them to the height of ten and twelve feet. The grass is always cut away on the setting in of winter.

"The second portion of my work lies in the Champáwat pargana in Káli Kumaon, between latitudes 29° 15′ and 29° 20 and longitudes 80° 0′ and 80° 15′.

"The Champáwat Valley, nearly 5,000 feet above sea level, is very picturesque, covered as it is with villages and cultivation, and surrounded by hills covered with oak and chír. I came across several clumps of deodár (cedar) which are all considered sacred.

"When commencing work on this ground I found it very difficult to procure coolies and provisions as nearly all the inhabitants were down in the Bhábar.

"Most of the ground in this work is covered with forest, and is in some parts very precipitous.

"The road from Bharmdeo *viâ* the large village of Bilkhet to Champáwat is in a very bad state, as it is now never repaired. The new road from Bharmdeo to Lohághát *viâ* Champáwat is a fine, gently sloping one, and is kept in splendid order".

(24.) Mr. Todd marched into Kumaon to take up his work in the neighbourhood of Baijnáth. Towards its northern boundary and to the west in the direction of Bhadkot peak, it is lofty, steep, and densely covered with forest. In other parts, although there is a large proportion of forest, the country is comparatively open, and contains, in addition to a large amount of general cultivation, numerous tea plantations. Some of these plantations seem to have been abandoned, and others are only partially cultivated, which is perhaps owing to the planters having found out that a large poorly cultivated area is not so remunerative as a small one highly cultivated and richly manured. Mr. Todd has delineated his ground with minute accuracy, and has shown its varied character with excellent effect. He finished his work on the 11th April.

Mr. H. Todd.
Topography of the ground round Baijnáth.

(25.) The following are Mr. Todd's notes on the portion of country he surveyed.

"The ground sketched by me is chiefly composed of high ridges varying from 6,000 to 9,000 feet above sea level and mostly covered with dense forest of oak and pine, the oak confining itself to the western and northern ridges where the ground becomes more rugged and precipitous and rises to a higher elevation. The pine is to be found on comparatively more gentle and rounded slopes. Deodárs are only to be found in clumps, and chiefly about temples. The largest clump is to the extreme south of my work, the wood of which is utilised by Government for bridges &c. in the vicinity. The valleys are mostly all open and the greater portion of them is under heavy cultivation. The Baijnáth valley is the only one where a good portion of the ground lies waste, owing to a description of grass difficult to uproot, and destructive to all cultivation. The roots of this grass have been known to penetrate through those of the tea plant.

"From the number of tea plantations scattered through my work planters seem to have been under the impression that the ground was well adapted for such cultivation, but judging from the number deserted and the condition of others I presume this is not the case. The largest and most productive of the plantations are Kosáni and Dunagiri, but a good portion of the latter has been allowed to run waste.

"The roads intersecting my work run for the most part along the valleys, through cultivation, and are of easy slope and in fair order. The principal one keeps along the Kosi till within half a mile of Kosáni tea plantation when it ascends the ridge that forms the watershed of the Gumti and Kosi rivers; then, with a stiff descent of two miles on the north face of the ridge, runs through very

open ground, passing through Baijnáth and crossing a high range on the north, descends into the Pindar Valley, keeping along the south bank till its junction with the Alaknanda, where one road branches off north to Karnprág, and another to Srinagar. At right angles to this road and starting from Sameswar is a very fair road to Bageswar which, with a gradual slope, ascends the Mansári gadh and, crossing a wooded ridge which closes the valley on the east, dips down into the Sarju Valley. At the point where this road branches off from the main one another leaves in an opposite direction, along the Sali gadh, towards Dwáráháth. Higher up another road starts from Baijnáth keeping along the left bank of the Gumti with a tolerably easy slope the whole way to Bageswar. All the above high roads are practicable for laden cattle and mounted travellers."

Mr. T. Kinney.

(26.) Mr. Kinney accompanied my office and was employed on general current work. He has proved himself a very efficient assistant. In March I sent him for a few days, for training and practice in minor triangulation, to Mr. Ryall who was then working to the east of Haldwáni. On sending him back to my camp, Mr. Ryall reported that "Mr. Kinney showed great willingness and aptitude, and the little time that was devoted to his instruction was fully made up to me by him." The work he did while with Mr. Ryall is shown in the tabular statement on page 45—a

Mr. E. F. Litchfield.

(27.) Mr. Litchfield marched into Kumaon with Mr. Peyton to take up the plane-tabling of the country immediately to the west of Mr. Peyton's ground. Mr. Litchfield, although he had had some training in plane-tabling on large scales, had never done any independent work on the 1-inch scale. Mr. Peyton was accordingly directed to see him start work, and give him any assistance that might seem necessary. Mr. Peyton considered that his supervision was only necessary for the first day: on the second he left, and Mr. Litchfield continued his work alone. At first Mr. Litchfield worked slowly, but he took great pains, and what he turned out, if its area is not very large, I found on inspection to be accurate and satisfactory. At the end of the season he was working at a fair rate, and his sketching had then improved considerably in style. He closed work on the 13th April.

(28.) The following are Mr. Litchfield's notes on the part of the country he surveyed.

"The Lamkeswar range runs through my work nearly east and west, and is steeper on the south side than the north. The top and higher portions of the ridge are densely wooded, but the valleys and lower spurs are mostly cultivated. The ground near Gangolihát is undulating and nearly all cultivated; and that to the east of Rameswar is like a basin, and also nearly all under cultivation.

"The Pitorágarh road is very steep and bad on either side of Gangolihát where it descends to the bridges over the Sarju and Rámganga. A much better road is the one from Lohághát to Pitorágarh which crosses the Sarju about two miles and a half below Rameswar. A fair is annually held at Rameswar at a spot on the right bank of the river just below the junction of the Sarju and the Rámganga. The river is fordable at the junction, but is very rapid lower down. At Rameswar there are several resting houses and a temple. There is very good fishing near Rameswar.

"Near the village of Bhaneswar there is a remarkable cave which is regarded as very sacred by the people. They believe that there are there four subterranean passages leading to the four sacred places Rameswar, Bageswar, Pacheswar and Sameswar, and my guide pointed them out to me as he led me along the cave. This cave is so constantly visited by the natives that the stones are as smooth as glass, and the rock perfectly black from the smoke of the torches.

"In the part of the country I surveyed, the villagers were very much harassed by packs of wild dogs which killed nearly every animal they came across. I never succeeded in shooting one, but some villagers brought me a pup that they had caught while the pack were devouring a deer. It was of a dirty buff colour, with upright ears and a bushy tail, resembling a wolf. It refused all food, and died in a couple of days."

General Review of the field operations.

(29.) The time available for field operations was necessarily short, and that time was further curtailed about a month by bad weather. Bearing this in mind, the general out-turn of work is large; and its execution is, without exception, creditable to the assistants.

(30.) In the lower parganas immediately above the Bhábar it is impossible, during the winter months, to obtain carriage and supplies on the spot; for these districts are then deserted by their inhabitants who go to carry on their cultivation and graze their cattle in the Bhábar. It was, therefore, necessary in these deserted districts to go to the expense of hiring permanent coolies from elsewhere.

(31.) The Bhábar districts in the neighbourhoods of Káli Dungi and Haldwáni are densely populated during the winter months by cultivators from the higher districts, and also by a large number of idlers and cattle grazers who come down to enjoy the mild climate of the Bhábar, but who do not assist in its cultivation.

(32.) During the field season there were no deaths from disease, and only one by an accident. A khalási working with Mr Ryall fell over a precipice and was killed on the spot.

There were several cases of fever and dysentery, due probably to the large amount of bad weather experienced during the season; and two men in my camp were attacked by small-pox, but by taking the usual precautions it did not spread. On the whole the health of the party was good during the field season, and the men worked willingly and well.

(33.) Before leaving the subject of the field operations, I beg to acknowledge the assistance which has in general been rendered to me by the civil authorities. My thanks are also due to Captain Campbell of the Forest Department for the great assistance he afforded the Survey while it was being carried over the forest districts in his charge.

The present recess of 1872.

(34.) On returning to quarters, the computations connected with the triangulation carried on during the field season, and the preparation of the fair maps of the country sketched at the same time were taken up. The fair maps (four in number) will be ready for publication before the end of the recess.

Death of Lieutenant H. M. Chambers, R.E.

(35.) On the 30th May of the present recess was announced, to the deep regret both of myself and all the other members of this party, the sudden death of Lieutenant H. M. Chambers, R.E. He joined us on the 1st July 1871, and since then, up to a few days before his death, he had been working among us faithfully and well, winning respect and regard both on account of his attainments, and his amiable and manly character. The Department has lost in him a most promising officer, and I feel sure that his untimely death has been felt as a personal sorrow by all who knew him.

(37.) Since the commencement of the recess the Assistants have been employed on computations and mapping. They are doing good work, and are giving every satisfaction. The native draftsmen also are working diligently and well.

Extract from the Narrative Report—dated 6th September 1872—of Captain J. HERSCHEL, R.E., Offg. Deputy Superintendent 1st Grade G. T. Survey, in charge No. 1 Extra Party.

The present Report has been delayed in the hope that some results of the last field season's operations, similar to those contained in postscripts to my former reports, might be included in it. Unfortunately I am not able to append them, the reductions being still incomplete. It must therefore be confined to narrating the movements of the party, the distribution of the stations of observation, and such details of method as may seem of interest.

(2.) This was the 3rd season during which the Zenith Sector had been in use. It was, on arrival, to be employed in determining latitudes along the southern half of the Great Arc, *viz.* from Cape Comorin to Elichpur; at such intervals, of a degree or more, as the nature of the country would permit or indicate as advantageous. During the two previous seasons it had been used in this way at Bangalor, at Cape Comorin, at two intermediate localities, and lastly near Ballári (Belary). It remained to fill up the gap between the last named station and Elichpur. This has now been done; somewhat less thoroughly perhaps than might have been originally hoped for—two of the intervals being rather large but as uniformly and completely as various difficulties and other considerations would permit.

(3.) About this time last year it had been decided that the Solar eclipse which was to occur towards the middle of December should be taken advantage of. Previous experience of work of the special kind contemplated led to my being directed to arrange to be present. It thus came about that it was not till the 20th of December that I was free to join my camp in person. The delay however was not so great on this account as would seem to be the case, as the first station to be visited was not far short of a month's march from Bangalor, and preparations (not requiring my presence) were necessary, which would occupy another week or ten days.

(4.) In effect the party left Bangalor in the beginning of November, about 15 or 20 days later than I should otherwise have directed. This had to be made up by extreme economy of time during the following months, as under any circumstances there was plenty to do; and eventually by staying out in intense heat, longer than any body liked. However the work was accomplished. The gap mentioned above was filled up by 4 groups of stations which I will now proceed to indicate more precisely.

(5.) They are named the Darur,† Kodangal, Somtana, Badgaon, groups, after the principal stations round which they are respectively situated. The last three of these were, in a measure, obligatory; being stations at which our late lamented comrade and fellow-labourer, Captain Basevi had taken pendulum observations for the determination of the local force of gravity. The first is in the tract known as the *Rúchur Doáb*, between the *Tungábudra* and *Kistna* rivers about 25 miles east of the well known Railway Station of the above name. The last is about 20 miles S.W. of Amráoti, in east Berár. The others are at intermediate points in the Haidarabad Territory. I may here conveniently give the geographical positions of the 9 groups which form the subject of this and the previous two reports, as well as of some other points along the same meridian at which latitudes have been observed in former days; with a view to showing the distribution.

TABLE of Southern Arc Latitude Stations.

Name of Group (G) or Station (S)		No. of Stations	Approx. Lat.		Approx. Long.		Initial of observer and year of observation Lambton (L) Everest (E) Waugh (W) Campbell (C) Herschel (H)
			°	′	°	′	
Cape Comorin	G.	6	8	13	77	44	**L.** 1809 (at Punnæ); **H.** 1871.
Mallapatti	G.	4	9	29	78	3	**H.** 1870-71.
Pachapáliam	G.	3	11	0	77	45	**L.** 1806; **H.** 1870.
Bangalor	G.	3	13	3	77	40	**L.** 1805 and 1806 (Dodágunta); **H.** 1870.
Paugarh	G.	2	14	3	77	25	**L.** 1805-06 Paugarh and Bomásundrum.
Honúr	G.	5	14	54	77	8	**H.** 1871.
Namthabad	S.	1	15	6	77	40	**L.** 1811.
Dárúr	G.	5	16	12	77	44	**H.** 1871-72.
Kodangal	G.	5	17	8	77	42	**H.** 1872.
Damergida	S.	1	18	3	77	43	**L.** 1815, **E.** 1825, **W.** 1840-41.
Somtána	G.	4	19	5	77	42	**H.** 1872.
Badgáon	G.	4	20	44	77	39	**H.** 1872.
Ashti	S.	1	21	3	77	40	Unknown.
Ládi	S.	1	23	9	77	45	**C.** 1864-65. [65, and 1865-66.
Kaliánpur	S.	1	24	7	77	42	**E.** 1825, **W.** 1839-40, **E.** 1840-41, **C.** 1864-

(6.) In the above table I have indicated the year, and name of previous observer, where there was occasion. It will be understood that the concurrence of Colonel Lambton's name with mine implies that he had observed at *one* of the stations composing my group.

(7.) Had circumstances admitted of it a group, or station, would have been desirable between *Ashti* and *Ládi*; but an interval of 2° though greater than what has been aimed at, is not exceptional, and is of no real consequence.

(8.) I may remark that I have reason to believe that, apart from constant errors (which a precise knowledge of the instrument which he used and of his method of observing can alone enable us to surmise—and these are not forthcoming) Colonel Lambton's observations are sufficiently good to be included in the list; and that I have been engaged at intervals in reducing them. The main difficulty is the labour of computation, owing to the want of the requisite astronomical tables, for reducing for the apparent motion of the stars, for those early years. I hope however to be able to deal with this satisfactorily as soon as the current work is further advanced.

(9.) The 4 groups which I have named as representing the last season's out-turn contain 18 stations of observation viz. 5, 5, 4, and 4 respectively. Of these the precise geodetic positions of the first two groups, viz. those about Darur and Kodangal can alone be considered available for immediate comparison with the astronomic values—the principal triangulation which was being conducted by Lieutenant M. W. Rogers R.E., along the line of the Great Arc northwards from Bangalor, having been overtaken at the last named station. The next group in order—that of Somtana—surrounds (but does not include) the principal station so named. It was considered on examination to be both unsuitable and difficult of ascent—in fact impracticable. I could not but admire, though feeling it undesirable to imitate, the zeal which must have animated Captain Basevi in accepting such a station for his operations. He had camels however, and I had carts. Whether he was able to take any of them to the top, I do not know;

† Lieutenant Rogers' Darrur.

but I should have had to depend wholly on *coolies*, and the delay would have been serious. The determination of the astronomic latitude at 4 neighbouring points round about the hill will, I believe, answer the purpose nearly if not quite as well. Of the BADGAON group it is sufficient to say that a direct comparison with the geodetic position will be possible at once, at the central station; but at the outlying three which complete it, only whenever these shall be trigonometrically connected.

(10.) I have next to mention a few changes in the routine of observation, which were introduced with the object of eliminating constant errors. (See paras: 16 and 17 of last report). To obviate the liability supposing it to exist, of the microscope run changing its value from time to time, the following rule was framed. *Whenever the index minute to be recorded is* 2 *or* 7, 12 *or* 17 *&c., the microscope reading is to be taken from the upper and lower graduations, both readings being entered in the record.** The record is thus made to supply directly a current check on the run, and data for a corresponding correction; and possibly, if continued, for an examination of the graduation. Runs were obtained in this way in the course of work, at about 200 different readings; and, as far as they go, they prove that at no single one of these is the graduation notably false: the evidence is insufficient to establish more as yet. They do however establish that the "run," though on the whole constant, *is* liable to slight alteration at different stations, thus justifying the practice.

(11.) In my last report I mentioned that a peculiar source of error seemed to exist in the levels of this instrument. Being unable to account for it, but feeling that it directly vitiated the results, I resolved on the first opportunity to put in practice a design I had for reversing the instrument on its pier, and then to take a set of observations in the reversed position. The opportunity was supplied by the Ballári Treasury. [Being just about to cross the Kistna and move far into the Haidarabad Territory a supply of coin was essential, but this I could not get for a long time.] The reversal of which I speak was effected by introducing a small metal button under the centre of the instrument, after prizing the latter up on one side with a lever. On lowering it upon the button a condition of unstable equilibrium obtained in which the instrument could be turned round, so to speak with a finger, with perfect safety, the feet just grazing the stone slab on which the instrument stands. On trial the method proved so satisfactory that I was perhaps too easily convinced, when I came to reduce the observations provisionally, that it was imperative to put it in practice at every station. I am far from saying that the conclusion was wrong; only that later experience raises a doubt whether the constant error which I *did* detect in *that* instance will be traceable in all. One thing is certain that, as in all cases of reversal, one or more of the class of constant errors will be eliminated. It will be eminently satisfactory if the practice of reversal, as carried out during the remaining 14 stations, should prove that the eliminated errors are insignificant in amount. Still more if it should appear that, but for it, the whole season's work would have contained errors which could not have otherwise been proved to exist. For the sake of past work however, I am in hopes that some definite conclusion may be arrived at which may rescue it from that suspicion.

(12.) As a rule from 30 to 35 stars were observed each night; and two full nights, or even two nearly full ones, were considered sufficient for each station—the instrument being in the reversed position on the second. In general the stations of a group are within a short march of each other; so that it was possible in good weather, to begin a new station every 3rd night. Thus the Kodangal group of 5 stations occupied only 15 nights (February 4th to February 18th) from first to last. The next would have been done at the same rate, but for an accident † in putting up the instrument at the last station. The damage sustained was repaired during the day, but the anxiety and labour of effecting it (thermometer 95°—100°) prevented my getting a good night's work, and then the weather changed. By still further reducing the number of stars, this speed might be kept up; but as it was, nothing but the necessity of getting through the work could have reconciled me to the wearisome round of putting up or taking down the instrument *at least every other day*. At every station too—and indeed every night almost—the meridional direction has to be sought out by transits, and adjustments repeated, before the regular work can be commenced, all of which though harassing does not shew in the record. Latterly this had generally to be done with the thermometer at or about 105°. The external temperature recorded at the last station, on the last night, on commencing work at 7-40 P.M., is 98°; falling however to 80° by 3 A.M. at which hour the Sector and observatory were taken down (for the last time) by moon-light, and a march of 8 miles effected.

(13.) This station was within half a mile of a Railway station (Nágpur branch): but on the last day—when all the arrangements were complete for breaking up the camp and returning by rail to Bangalor at once—we learnt to our disappointment that we could not use it, but must march down the line to the next principal station, some 16 miles distant.

* I give this rule in full, because it seems to be suitable for adoption generally in azimuthal as well as vertical observations. It increases the number of microscope readings by 1 in 5 (or less if relaxed)—but removes all possibility of overlooking an erroneous run.

† A full report was communicated at the time. The injured part has been since re-examined and nearly all trace removed.

(14.) Thus ended the most exhausting field season, which I (individually) have experienced. To those of the party who entered upon it six weeks earlier than I did, with a march of 240 miles, the latter portion with its intense heat must have been still more trying. The table which I have given shows that the latitude of 20° 44′ was reached, that of Bangalor being 13° 0′. This difference represents a direct distance of nearly 550 miles which was of course largely exceeded by the wanderings in the Haidarabad wildernesses, where no road ever was. Much of the country traversed was unutterably stony, and unsuited for wheeled carriage, which is almost unknown there. The long distances which had to be gone over to get from one group of stations to another supplied leisure it is true, for the partial reduction of the observations, thus in some measure redeeming the time otherwise so fruitlessly expended; but I may conclude this narrative with the earnest hope, that no party engaged in work of this kind may ever again have to go over so much ground in search of suitable sites.

(15.) I very much regret that I cannot produce any final numerical results. So far as an estimate may go, however, I may hazard the conclusion that a remarkable disturbance of attraction will be found by comparison of the astronomic and geodetic amplitudes between HONUR and DARUR. These groups are only 1° 18′ apart, yet there seems to be an abnormal attraction producing a discrepancy of nearly 9″ of arc—the presumption being that the plumb line is drawn north-wards at the northern station by nearly the whole amount.

(16.) The same presumed effect is somewhat modified at the next group, 0° 56′ to the the north, where it amounts to only 6″ or 7″. It is about the same at BADGAON. This presumption rests mainly on the general agreement (except at Bangalor) of the astronomic and geodetic values at all the southern points and, *with a reservation as to the correctness of the adopted ellipticity with which the latter are computed*, on the absence of any bias towards one sign or the other in the *apparent* local deflection in other parts of India. I believe this is the largest deflection yet found in this country, which may not be directly attributed to mountain masses.

(17.) There does not appear to be—so far as I can yet judge—any strong additional evidence of the *sensitiveness* of local attraction to *small* change of place. It is traceable indeed, but not with sufficient distinctness to require me at present to add to what I have already said on this subject in a former report.

(18.) The health of the party has, on the whole, been exceedingly good. Two cases of small pox occurred, but both happily recovered. Of these the Native Doctor—Hospital Assistant I. Soveriappen whose name I mention specially as having caught the disease in the performance of his duty—supplied one. Vaccination was resorted to to check the liability to infection, at the small military station of Hingoli which we happened to reach at the time. I may mention that this was the only Station which we approached during the season.

POSTSCRIPT, dated 30th September 1872.

(19.) The reduction of the observations described in the body of the report having now been brought to an end—though much remains to be done towards tracing errors to their source—I am enabled to summarize the principal results. It will be convenient to exhibit them in the same tabular form as before. In explanation of the Table which follows it is only necessary to say that the Geodetic latitudes of the first two groups are those furnished by Lieutenant Rogers and are based on the astronomic latitude of a point near * Calcutta; while that of Badgáon S. though in the same terms, *i.e.* derived from the same origin, has been obtained by applying the geodetic amplitude (according to Everest) between BADGAON and DUDALA—the northernmost point to which Lieutenant Rogers' operations extend—to the latitude of the latter station furnished to me by that officer. At the time of writing the body of this report—in which it will be seen that I have estimated the difference at Badgáon at 6″ or 7″ instead of 11″—I had overlooked the fact which has now been forced upon me by the discrepancy between the latitude so obtained and that given in Everest's "Meridional Arc" (and which I find mentioned in the 26th paragraph of Colonel Walker's Report for 1868-69)—a discrepancy of 4″ in latitude generated in the triangulation between Kaliánpur and Calcutta.

(20.) The whole of the triangulation of Southern India derives its latitude element from the *astronomic latitude of Calcutta, which was supposed to be nearly identical with that which would be assigned by good triangulation emanating from the origin Kaliánpur*. This supposition was based on the assumption that the existing triangulation, though admittedly inferior, would not prove so misleading as it is now known to have been. The result is important. All latitudes derived from the *Calcutta* origin must be diminished by 4″ to make them comparable, geodetically, with those derived from *Kaliánpur*: or, *vice versâ*, the latter must be increased by 4″. This is equally applicable where the question is one of differences between astronomic and geodetic latitudes.

(21.) There is no virtue in the astronomic latitude of Kaliánpur any more than in that of Calcutta, or of any other point where direct observation might have supplied an origin for computed latitudes; and if we assume that the Calcutta latitude was unaffected by local attraction, then that of Kaliánpur is too small by 4″ and a correction of—4″ must be applied to all values of $\lambda_o - \lambda_c$ in Northern and Western India while those shown in the present Table need no such correction. On the other hand if we assume that the Kaliánpur normal is true, and not locally deflected, all the said values of $\lambda_o - \lambda_c$ stand unimpeached, while the present ones must receive a correction of + 4″. In any case however there is only a change in local disturbance between *Kaliánpur* and BADGAON of 7″ instead of the 11″ which, for the sake of uniformity, I am obliged to show in the Table.

(22.) The difference of latitude between Badgáon and Kaliánpur is 3° 20′ and the change in disturbance is 7″, or about 2″ per degree. This is not much when we remark that a change of 1″·7 may occur (as between XXV and XXVI or between XXVII and XXVIII) in about 8 or 10 miles. But a little further South we find—from HONUR to DARUR, distant from each other only 1° 15′ in latitude and 35′ in longitude *i.e.* 98 miles,—a change of 8″. It is absolutely impossible to admit that any errors of measurement can account for more than a small fraction of this amount and therefore the conclusion cannot be avoided that the attraction is disturbed in a grossly irregular way, which makes it a matter of indifference, so far as any question of Figure alone is concerned, whether the results are rigorously correct or not.

(23.) And now as to the degree of accuracy to which these may lay claim: I am not in a position to say what the "probable error" is theoretically; but judging from the accordance *inter se* of results depending on the observations of successive nights taken severally, it is pretty safe to say that no one of the co-latitudes given above is in error so much as one-tenth of a second.

(24.) The effect of reversal has been investigated closely, without any more decisive results than these—1st The observations are very slightly biassed by position: but the effect is barely traceable because 2nd They are all subject to errors of greater magnitude, which take effect in an intermittent way and seem to be due to the positions of the bubbles in the levels. Errors of this class affect the observations in groups, and if a night's work consists of only one or two such groups, the mean result for that night has often a large error from this source, which masks that which might otherwise be more confidently attributed to the orbiculation of the instrument.

(25.) On the whole, there is insufficient justification for any alteration of previous results on this account, but the system of reversal has obviously so much in its favour that in my opinion it ought never to be neglected in future operations. And, with regard to what I have said above about an irregularity in the levels affecting groups of observations, I suggest the propriety of *purposely* and *frequently* altering their readings during the course of work, and of making a re-adjustment of level, say every hour, a part of the routine. The level corrections are the weak point: it is fitting that they should receive the most attention.

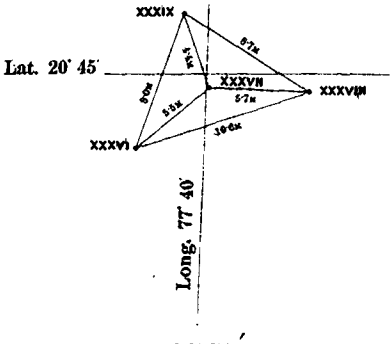
Comparison of Astronomic and Geodetic Latitudes. 1871-72.

Number of Station and Name of Group	Geodetic		Co-latitude		Difference $\lambda_o - \lambda_c$	Difference from Mean
	Latitude	Longitude	Geodetic	Astronomic		
	° ′ ″	° ′ ″	° ′ ″	″	″	
Cape Comorin Group ...	8 13 ...	77 44 ...	81 47 ...	...	− 0·13	
Mallapatti „ ...	9 29 ...	78 3 ...	80 31 ...	...	0·42	
Pachapáliam „ ...	11 0 ...	77 45 ...	79 0 ...	...	1·49	
Bangalor „ ...	13 3 ...	77 40 ...	76 57 ...	...	6·62	
Honúr „ ...	14 54 ...	77 8 ...	75 6 ...	...	0·10	
XXII ...	16 9 54·33	77 36 39	73 50 5·67	13·36	− 7·69	+ 0·51
XXIII ...	6 30·96	43 54	53 20·04	28·14	+ ·10	
XXIV ...	7 57·50	48 19	52 2·50	11·21	− ·51	
XXV ...	17 23·07	46 58	42 36·93	46·02	− ·89	
XXVI ...	18 9·60	37 17	41 50·40	57·80	+ ·80	
Dárúr Group ...	16 12 ...	77 43 ...	73 48 ...	...	− 8·20	...
XXVII ...	17 4 8·71	77 38 50	72 55 51·29	59·01	− 7·72	− 1·18
XXVIII ...	7 19·33	44 56	52 40·67	46·68	+ 6·01	+ 0·53
XXIX ...	8 0·01	40 53	51 59·99	66·40	+ 6·41	+ ·13
XXX ...	10 56·61	36 57	49 3·39	9·67	+ 6·28	+ ·26
XXXI ...	11 3·10	43 35	48 56·90	63·17	+ 6·27	+ ·27
Kodangal Group ...	17 8 ...	77 41 ...	72 52 ...	...	− 6·54	...
XXXII ...	19 1 ...	77 40 ...	70 58 ...	38·39	...	...
XXXIII ...	2 ...	46 ...	57 ...	17·23	...	...
XXXIV ...	9 ...	44 ...	50 ...	35·65	...	...
XXXV ...	• 7 ...	38 ...	52 ...	45·35	...	...
Somtána Group ...	19 5 ...	77 42 ...	70 55 ..	...	...	...
XXXVI ...	20 41 ...	77 35 ...	69 18 ...	37·76	...	...
XXXVII ...	44 26	39 ...	15 33	44·45	−11	...
XXXVIII ...	44 ...	44 ...	15 ...	56·67	...	...
XXXIX ..	48 ...	37 ...	11 ...	52·86	...	...
Badgáon Group ...	20 45 ...	77 39 ...	69 15 ...	...	−11	...

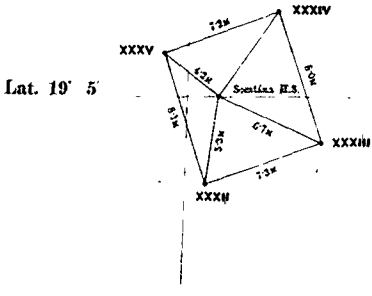
NOTE.—λ_o λ_c stand for observed and computed latitude, or distance of zenith from the equator. When $\lambda_o - \lambda_c$ is + λ_o or the observed distance, is greater than λ_c or the computed distance; *i. e.* the astronomic is **N** of the geodetic zenith and therefore the plumb-line is deflected towards the South. *Vice versâ* when $\lambda_o - \lambda_c$ is − (as above) the plumb-line is deflected towards the North.

ROUGH CHART TO ILLUSTRATE POSITIONS OF ZENITH DISTANCE STATIONS 1871-72.

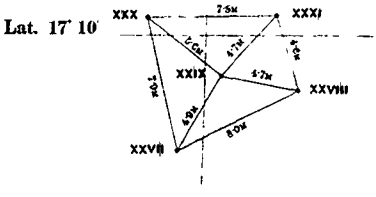
BADGÁON GROUP



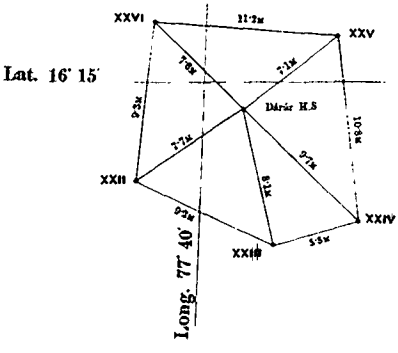
SOMTÁNA GROUP



KODANGAL GROUP



DÁRÚR GROUP



C. DYSON, Photo.

C. G. OLLENBACH, Lith.

Photozincographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Dun, November 1872.

Extract from the Narrative Report—dated 1st May 1872—of J. B. N. HENNESSEY, Esq., Deputy Superintendent 1st Grade, G. T. Survey, In charge Computing Office.

On 1st May 1871.

PERSONNEL.

J. B. N. Hennessey, Esq., .. Deputy Superintendent 1st Grade.
W. H. Cole, Esq., M.A., .. Assist. Superintendent 1st Grade.
Lieutenant H. M. Chambers, R.E. Do. 2nd Grade.

Computing Branch.

Mr. C. Wood.
Bábu Gunga Pershad.
„ Cally Mohun Ghose.
„ Kally Coomar.
„ Gopal Chunder.
and 8 other native computers including map and record keeper and librarian.

Printing Branch.

Mr. M. J. O'Connor.

(1.) The following changes have occurred in the establishment of the Computing Office, during the last 12 months. Lieutenant H. M. Chambers, R.E., having completed his course of instruction, was transferred to the *Kumaon and *Gurhwal Party on 1st July, and Mr. Peychers, Assistant Surveyor 1st Grade, was transferred to this office on 1st September: a vacancy created by dismissal was duly filled, and nominations made to four other computerships of suitable candidates. Also, the retirement of Mr. W. H. Scott on pension, led to the appointment in his place, as head of the Drawing Office, of Mr. G. W. E. Atkinson, Surveyor 4th Grade, on 1st April 1872; Mr. Atkinson having joined this Office on 1st January 1872.

Calculating Branch.

Computations.

(2.) The circuits of the triangulation included in the Sironj-Chach quadrilateral having been made consistent, as described in my last report, there remained a large amount of calculation, chiefly in connection with the auxiliary principal stations, to complete the triangulation in question. Accordingly, 268 triangles, entering in groups of 2 and upwards into 110 figures, were subjected to the usual conditions and made consistent by the method of least squares; so that the whole mass of this work now stands reduced by the most accurate of modern processes, which is certainly not more elaborate than is due to the very superior quality of the field operations. The computations of the principal stations involved 818 triangles, 115 new deductions (double) of latitude, longitude and azimuth, and verification and correction of several hundred deductions approximately calculated, all in duplicate.

Continued.

(3.) The ordinary computations performed are given in the following statement.

Subject	Quantity	
Numbered pages of, and indexed	41 vols: of angle books.	
Mean readings examined or computed, ...	47 openings ditto.	
Abstracted observed angles, ...	704 angles.	
Computed zero means and general means, ...	370 do.	
Compared abstract of observed angles, ...	733 do.	
Computed latitudes, longitudes and azimuths of Secondary Stations,	88 single deductions.	In duplicate
Do. weights of observed angles	450 angles.	
Do. differences of heights of Principal Stations, ..	1500	
Do. circumpolar Star observations for azimuth ..	14 stations.	
Do. "indeterminate factors" in terms of errors, ..	4 compound figures	
Do. observations for time, ...	25 sets.	
Do. reduction of Meteorological observations ..	Twice a day throughout the year.	

Secondary Triangulation.

(4.) The principal triangulation having been computed, as already described, it became necessary to take the secondary work into consideration: points of this class are frequently valuable for purposes of after survey and their value is rapidly on the increase with the demand for Railways, Roads, Canals &c., and the surveys these projects entail. Considerable care and discrimination are, however, essential in dealing with the Secondary triangulation, so as to secure its full utility on the one hand, and on the other to avoid redundant calculations, which if attempted would probably lead to more work than could be accomplished. In view of these

Calculating Branch.—(Continued.)

desiderata a general scheme is being elaborated in connection with the subject under notice, and a suitable process has been devised for producing the consistency required in these operations: the method of calculation has been applied in 3 instances, and it appears to meet the required want satisfactorily.

Compilation of Calculations.

(5.) The results compiled for the press are as follows:—1 simple and 3 compound figures, and 11 quadrilaterals; pages 192 of Synopsis of Principal Stations Latitudes, Longitudes, Azimuths, Differences of Height, Heights and Descriptions of Spirit-levelled Bench-Marks; pages 200 of Observed Azimuths; and 17 pages of Spirit-levelled Stations of season 1870-71.

Compilation of data for Numerical Charts, and examination of the same.

(6.) Besides the compilation of computed or observed results, to be set up in book form, noticed in para. (5), a somewhat similar procedure is required for numerical charts and their accompaniments to meet the urgent wants of surveys now in progress. In the absence of such charts, a manuscript copy of numerical tables has to be prepared for each applicant; and this work must needs be *repeated* for adjacent operations at least, at a loss of time and liability to mistakes which all repetitions must involve: add to this, tables without diagrams lose a sensible portion of their value. As an effectual remedy for all these drawbacks, Colonel J. T. Walker, R.E., Superintendent G. T. Survey, devised an extension of the details formerly given on charts; so that his modern numerical chart supplies all essential numerical and descriptive facts, chiefly on the diagram or chart of triangulation itself. The numerical chart thus composed is photo-zincographed, so that facsimiles are available at a moment's notice. It will however be readily seen, that the value of these charts falls to zero, unless scrupulous care is exercised to secure *accuracy* in the preparation of the single manuscript required for copying or reducing with the camera; in fact, each such chart, of so much value to every Survey Executive, is a diagram illustrated with the epitomised results of a small volume. It therefore follows, that the required compilation of data for Charts and examination of proofs, involves no little labor at the outset, though the result is highly satisfactory and economical in the end. During the twelve-month under notice, 4 numerical charts were compared against the original computations, and data compiled for the following:—

	CHARTS.
Northern portions of *Bombay triangulation, ...	3 sheets.
South Konkan Series, ...	1 „
Great Indus do.	7 „
Gurhágarh, do.	1 „
Rávi and Chináb Minor Triangulation, ...	2 „
Bider Longitudinal Series, ...	1 „
Assam Valley do. (1870-71), ...	1 „
Gora do.	2 „
Rahún do.	1 „
Great Arc do. (1869-70), ...	2 „
Biláspur do.	1 „
Great Arc do. (N. Section), ...	6 „
N. W. Himalaya do.	2 „

Also, a synopsis of sides for the whole of the Sironj-Chach quadrilateral was prepared, for plotting diagrams to illustrate the "reduction of figures" given in the printed volumes passing through the press.

Instrumental work.

(7.) Consequent on orders by the Government, a careful comparison was made between two spirit levels, one by Messrs. Cooke & Sons, the other by Messrs. Troughton & Simms, and a suitable line was levelled over by Mr. C. Wood and the undersigned with the view of affording data for reporting on the relative merits of these two instruments. The use of a 1st-class Theodolite and the departmental method of observing azimuths were taught to Lieutenant J. Hill, R. E., Mr. W. H. Cole, M. A., and Mr. W. G. Beverley. Twenty-five sets of observations were taken for time. And meteorological observations, twice on every day of the year, were made as usual at Dehra Dun Observatory, and the reduced results supplied to the reporter on meteorology, N. W. Provinces†; also similar observations were taken at Masúri for about 6 months.

Protection of Stations.

(8.) The correspondence, lists and descriptions involved in the protection of the G. T. Survey stations have been persevered in as heretofore, and I need scarcely add that such protection is hardly of less importance than the primary surveying operations. The station marks are essential for all after surveys, and will serve the required purposes for an indefinite number

† *Cost of maintenance of Meteorological Stations.* This seems the proper place to state that the observatory at Dehra costs the Meteorological Department nothing; both the establishment and the instruments belong to the Great Trigonometrical Survey. *(Report for 1871 on Meteorological observations N. W. Provinces, by Murray Thomson Esq., M.D., F.R.S.,E.)*

Calculating Branch.—(Continued.)

of years; rigorously speaking, points once destroyed cannot be restored without a repetition of the original work, and at a corresponding cost of time and money; and it is easily understood, that in the absence of all such points, the value of the operations by which they were fixed is materially diminished, at least so far as posterity is concerned. Fully recognizing this fact, Colonel Walker, with the approval of Government, established the system of protection now in force. It is, however, a matter for regret, that what appears a simple duty, so plainly set forth in Colonel Walker's instructions, should entail a considerable amount of work in repeatedly preparing copies of the same lists for local officers, in calling their attention to defective returns or to the absence of all returns, and in repeating explanations and directions which are either lost or disregarded. I can only hope that in course of time these drawbacks will gradually disappear. During the past 12 months, about 400 letters and dockets have been written on the protection of the G. T. Survey principal stations; 33 duplicate or supplemental lists of 155 stations have been supplied to the local officers, and check lists of 661 stations in 93 districts have been prepared for reference in this office. In all these duties, Mr. C. Wood has rendered valuable assistance.

Miscellaneous.

(9.) The following are some of the miscellaneous duties discharged. Prepared Tables of Stars common to the two 7-year Greenwich Catalogues; also, Tables of Colonel Lambton's Zenith distances, and 2 copies of Synopsis of results of the Quadrilateral Sironj-Chach. Compared, examined and passed for the press the whole of the work, comprising 1,143 pages, mentioned hereafter under the head of "Printing Office." Instructed Lieutenant H. M. Chambers, R. E. in the computations of the department. Supplied data to 23 officers, involving a considerable amount of computation as well as compilation. Examined 2 candidates for the junior branch of the G. T. Survey, &c., &c., &c.

Photo-zincographic Branch.

(10.) The work performed by the Photo-zincographic Branch is given in the following table, under the heads of Maps, Numerical Charts, Plates and Diagrams, and Professional and Office forms.

Maps

Subject	When published	No. of parts	No. of copies printed
Prints of maps published in former years, ...		51	1497
Routes between the Panjáb and Eastern Turkestán, ..	May, 1871.	1	66
Masúri and Landaur sheet No. 10 skeleton, .. .	„ „	1	111
„ „ 10 contoured, ...	„ „	1	102
„ „ 20 „	„ „	1	132
Guide Map to Masúri and Landaur, (1st edition)	„ „	1	44
Masúri and Landaur sheet No. 4 contoured, ...	June, „	1	105
„ „ 8 skeleton, ...	„ „	1	105
„ „ 8 contoured, ...	„ „	1	105
„ „ 1 „	July, „	1	105
„ „ 1 skeleton, ...	„ „	1	108
„ „ 2 „	„ „	1	107
„ „ 2 contoured, ...	„ „	1	105
„ „ 3 „	„ „	1	105
„ „ 4 skeleton, ...	„ „	1	108
„ „ 5 contoured, ...	„ „	1	107
„ „ 6 „	„ „	1	105
„ „ 6 skeleton, ...	„ „	1	105
„ „ 11 „	„ „	1	105
„ „ 11 contoured, ...	„ „	1	105
„ „ 13 „	„ „	1	106
„ „ 13 skeleton, ...	„ „	1	105
„ „ 22 „	„ „	1	106
„ „ 22 contoured, ...	„ „	1	105
„ „ 23 „	„ „	1	105
„ „ 23 skeleton, ...	„ „	1	107
„ „ 3 „	Augt. „	1	107
„ „ 5 „	„ „	1	107
Spirit Levelling operations No. 3, (3rd edition)	„ „	1	110
Kumaon and Gurhwal sheet No. 8 skeleton, ...	„ „	1	40
„ „ 9 contoured, ...	„ „	1	40
„ „ 24 „	„ „	1	40

Photo-zincographic Branch—(Continued.)

Maps

Subject	When published	No. of parts	No. of copies printed
Index to Guzrát Survey, ...	Septr. 1871.	1	474
„ Kattywar „	Octr. „	1	465
Spirit Levelling operations No. 14	„ „	1	105
„ „ 15	„ „	1	105
Eastern British Frontier skeleton, ...	„ „	1	26
„ contoured, ...	„ „	1	26
Dehli Map, ...	Novr. „	1	309
Index to Kosi valley Survey, ...	„ „	1	410
Guide Map to Masúri and Landaur (2nd edition) ..	„ „	1	222
Spirit Levelling operations No. 9	Decr. „	1	105
Kosi Valley Survey sheet „ 3 skeleton, ...	„ „	1	111
„ „ 3 contoured, ...	Jany. 1872.	1	105
Kattywar sheet No. 27	Feby. „	1	105
„ „ 28	„ „	1	105
Route map from the Panjáb to Badukshán, ...	„ „	1	441
Index to Level Charts, ...	„ „	1	480
Kosi Valley Survey sheet No. 1 skeleton, ...	„ „	1	105
„ „ 1 contoured, ...	„ „	1	105
„ „ 2 „	„ „	1	105
„ „ 2 skeleton, ...	„ „	1	105
„ „ 5 „	„ „	1	105
„ „ 5 contoured, ...	„ „	1	105
„ „ 6 „	„ „	1	105
„ „ 6 skeleton, ...	„ „	1	105
Chamba map, upper left half *(for Supdt. Chamba States)* ..	„ „	1	100
Kosi Valley Survey sheet No. 4 skeleton, ...	March, „	1	105
„ „ 4 contoured, ...	„ „	1	105
„ „ 7 „	„ „	1	105
„ „ 7 skeleton, ...	„ „	1	105
„ „ 8 „	„ „	1	105
„ „ 8 contoured, ...	„ „	1	105
Kattywar sheet No. 26, ...	April „	1	105
Chamba map, upper right half *(for Supdt. Chamba States)* ..	„ „	1	100
„ lower „ .. Do. do., ..	„ „	1	100
„ „ left half. . Do. do., ..	„ „	1	100
Mirza's route to Badukshán, ...	„ „	1	52
	Total	118	10131

Numerical Charts.

Great Arc Revision, season 1869-70, N. Section, ...	June, 1871.	1	66
Northern portions of Bombay No. 3, ...	„ „	1	65
„ „ 10, ...	„ „	1	67
Great Arc Revision, season 1869-70, S. Section, ...	„ „	1	65
Great Indus Series No. 3, ...	August, „	1	65
Northern portions of Bombay No. 6, ...	„ „	1	65
„ „ 5, ...	Septr. „	1	65
Great Indus Series No. 11, ...	„ „	1	68
„ „ 12, ...	„ „	1	66
Biláspur Meridional Series, season 1870-71, ...	„ „	1	66
Assam Valley Triangulation, season 1870-71, ...	Octr. „	1	65
Great Indus Series No. 1, ...	„ „	1	65
South Konkan Series, ...	Novr. „	3	65
Great Indus Series No. 2, ...	Decr. „	1	65
„ „ 4, ...	„ „	1	65
„ „ 10, ...	„ „	1	65
Bider Longitudinal Series, season 1869-70, ...	„ „	1	65
Northern portions of Bombay No. 8, ...	Jany. 1872.	1	60
Gurhágarh Meridional Series, seasons 1858-60, ...	„ „	1	65

Photo-zincographic Branch—(Continued.)

Numerical Charts.

Subject.	When published.	No. of parts.	No. of copies printed.
Khágán and Pesháwar triangulation, ...	April 1872.	1	8
Rávi and Chináb River triangulation, ...	„ „	3	64
Great Arc Revision, season 1870-71, N. Section, ...	„ „	1	65
	Total ..	26	1375

Plates and Diagrams.

Subject	When published.	No. of copies printed.
Bench-marks &c., &c.	June 1871,	520
	August „	483
	Septr. „	305
	Octr. „	498
	Novr. „	1087
	Decr. „	793
	Jany. 1872,	216
	Febry. „	1035
	Total, ..	4937
Professional and Office forms		13,655

7248 Maps and 547 Numerical Charts were issued during the year. The forms were expended as fast as they could be printed; indeed the demand was greater than the supply, so that I look forward to the arrival of the two additional presses despatched from England under orders from the Secretary of State for India. Contrasting the work performed in 1870-71 with that done in 1871-72, we have the following:—

Year.	Maps.	Charts.	Plates and Diagrams.	Forms.
1870-71	6,465	839	13,205	10,482
1871-72	10,131	1,375	4,937	13,655

Though the total number of prints of all sorts is about the same in the two years contrasted, a far larger amount of the elaborate kinds of work, maps and charts, has been performed: both these sorts of prints are photo-zincographed. Hitherto the forms were zincographed from pen transfers, to admit of introducing in new transfers such improvements as were suggested from time to time. It is, however, an advantage, in the cases of certain well-established forms, to take negatives of them, and this has accordingly been done in those instances where it appeared desirable.

(11.) An abstract of the work executed since 1866-67 is given below.

Subject	1866-67 No. of prints.	1867-68 No. of prints.	1868-69 No. of prints.	1869-70 No. of prints.	1870-71 No. of prints.	1871-72 No. of prints.
Maps, Charts and Diagrams, ..	7,118	7,376	5,538	12,315	20,509	16,443
Forms, ...	5,152	10,531	10,800	13,571	10,482	13,655

Typographic Branch.

(12.) The work performed by the printing office during the past year and since 1865-66 is concisely stated in this table,

	1865-66	1866-67	1867-68	1868-69	1869-70	1870-71	1871-72
Pages composed, ..	377	756	641	697	693	819	1,143
Do. printed, ..	53,329	93,411	126,696	155,025	106,231	234,828	241,348

the total pages composed during the past year may be subdivided under the following heads.

Observations and Calculations for the volumes of the Great Trigonometrical Survey in hand	..	547 pages.
Pamphlet of Levelling operations, season 1870-71	..	21 „
Report to the Government, season 1870-71	..	103 „
Data for Charts, Descriptions of Bench-marks, Routes, Professional Orders and Memoranda	..	472 „
Total	..	1143 „

Drawing Office.

(13.) The introduction of Photo-zincography for the purpose of copying Maps, Numerical Charts &c., has necessarily produced an influence on the Drawing Office where the originals to be copied are chiefly prepared: the draftsman now must needs draw under the conditions most favorable for the Photo-zincographic process; so that these two branches, the drawing and copying, are completely dependent on each other. This relation has induced an amount of general supervision of the Drawing Office at my hands, and recently when a small expansion of this office, to meet urgent demands, was sanctioned by the Government, the selection of candidates and the organization of this establishment devolved on me, in accordance with the orders of the Officiating Superintendent. I am glad to report, that the head of the Drawing Office, Mr. G. W. E. Atkinson, is now provided with a promising class of workmen, and I expect they will prove efficient assistants in time, under his care and training.

No. 4 Extra Party.

(14.) Captain W. J. Heaviside, R.E., received charge of this party from me on 20th April 1872, and as he has been good enough, at my request, to mention the duties discharged by me between 19th September 1871 (the date the party returned to Dehra Dun from camp), and transfer of the party to him, it is unnecessary for me to make any repetitions here. I may add that the duty of completing the late Captain Basevi's valuable observations has been entrusted to Captain Heaviside, and that in compliance with the Superintendent's wishes, I shall have much pleasure in assisting Captain Heaviside to become acquainted with the processes followed by Captain Basevi in taking Pendulum observations.

(15.) In concluding this report, I trust I may be permitted to express my acknowledgments of the services rendered by my assistants. Mr. W. H. Cole, M. A., continues to co-operate with me both cordially and with excellent results, and the general efficiency to which he has now attained enables him to originate projects of no little value. Mr. C. Wood is as valuable an assistant as ever; he is always ready to take a share in any duty whatever that may be in hand and he invariably works both quickly and well. Mr. Peychers has proved a useful and most willing hand and I fully expect that in course of time he will become as competent as he is willing. Bábu Gunga Pershad continues to render excellent service, and his experience combined with his steadiness and intelligence have enabled him to acquire a familiarity with the duties of this Office which he is always ready to make good use of. The services of Bábús Cally Mohun Ghose, Kally Coomar, Gopal Chunder and Tarapodo are deserving of commendation, nor have I reasons to be dissatisfied with the remaining computers; some of these are young hands who have been admitted on such excellent recommendations, that I expect to be able to report very favorably on their progress in due course. Messrs. Ollenbach and Dyson in the Photo-zincographic office continue to work willingly and effectively. Mr. O'Connor, the printer, is as efficient as zealous in the discharge of his duties.

Total Eclipse of the Sun. December 11-12, 1871.

(16.) This eclipse was observed at Utakamand, Nilgiri hills, Lat. N. 11° 24′, Long. E., 76° 49′, Height above sea level 8,642 feet, under the directions of Colonel J. F. Tennant, R.E., F.R.S., &c., who was assisted by Captain J. Waterhouse from the Surveyor General's Calcutta Office and by Captain J. Herschel, R.E., and myself from the Great Trigonometrical

Total Eclipse of the Sun. December 11-12, 1871.

Survey. Colonel Tennant has already written a report to Government on the expedition which he conducted, besides his communication to Dr. Huggins which appeared in the monthly notices of the Royal Astronomical Society, vol: XXXII No. 3, January 1872; in addition, I have my own report to Colonel Tennant on the part of the operations assigned to me: it may therefore be sufficient to make a few extracts from these papers, confining myself generally to those portions which touch on my own duties.

Extracts from Colonel Tennant's report to Government.

"The photographic operations were under the general charge of Mr. J. B. N. Hennessey of the "G. T. Survey, with whom was associated Captain Waterhouse, for the special purpose of attending "to the technical manipulations."

* * * * * * * * * *

"The lens employed was one of Dallmeyer's largest "Rapid Rectilinears" of 4 inches (10 c. m.) "aperture, and about 33 inches (83·7 c. m.) equivalent focus. This was attached to a cylindrical metal "camera, which was mounted on an equatoreal stand, and a clock was provided to keep the camera auto- "matically up to the object to be photographed" * * * * * *

"The camera was furnished with 6 dark slides, each to hold a plate 5" square." * * *

Extracts from Mr. Hennessey's report to Colonel Tennant.

(5.) "After due discussion and consideration Colonel Tennant decided that we should try to "secure 6 negatives during totality, and that the successive periods of exposure should be 5' 10', 15'., "15', 10', and 5'; this conclusion of course assumed that the sky would be free from cloud or mist. As "will be seen, these periods afford intervals of 10 seconds between consecutive negatives to change the "slides, besides a period to spare at the commencement and end of 5 seconds.

(6.) "Subject to these conditions we proceeded to rehearse our parts, Captain Waterhouse "changed the slides and opened and shut them. Mr. Willis † counted seconds 1 to 130 audibly, following "the hand of a chronometer placed before him, while I made the required exposure by uncovering the "lens, and also noted the limiting seconds. After a moderate amount of practice we found ourselves able "to carry out the prescribed programme leisurely and with certainty.

(7.) "I may here add a few words with respect to the counting. My agreement with Mr. Willis "was this: some 10 or 15 seconds before totality I was to call out 'mark 0": on this he should keep "repeating the word "nought" as the hand marked a complete second; meanwhile I was to watch the "sun and to give the signal "count," directly totality occurred; when in place of saying "nought," "Mr. Willis was to commence counting the seconds audibly, beginning with 1 and going on to 130, or "until I stopped him. I had a small paper board strapped to the back of my left hand on which I record- "ed the limiting seconds of each exposure. These arrangements were found simple and effectual, and under "favorable circumstances they would furnish the means of noting with some accuracy the times when tota- "lity began and ended. They however involve a very moderate amount of mental arithmetic from the "individual in my place, but the tax is so limited that most persons could do the needful after a little "practice.

(8.) "The morning of the 12th December dawned with but little promise of affording us a clear "view during the coming totality. The sky was free from cloud and the stars shone brightly at 2 A M; "a couple of hours later we were enveloped in a mist, which at times was so dense that objects only 50 yards "distant were hardly visible in the gray light of dawn: and as the light increased and we could see through "little gaps in the fog, there appeared floating below an endless mass of clouds, which the brisk "southerly breeze kept driving against us. Notwithstanding we went through the last rehearsal of our "parts, and at 20 minutes to totality *as agreed on* I gave Captain Waterhouse the signal to commence "immersing the plates.

(9.) "Some 10 minutes before totality I focussed the camera on the solar cusps, and about 5 "minutes later we were *all at our posts*: the first slide was in its place, the instrument was set and being "*driven satisfactorily, and we were ready to perform our parts* if permitted to do so: meanwhile the mist "*kept streaming persistently against us; it came up clinging to the surface of the hill* and in depth it "probably did not extend beyond 50 feet above us, but it was sufficiently dense to make the distant hills "appear quite dim and in addition it varied in density from one moment to another, thus making the task "of timing the exposures hazardous if not hopeless.

(10.) "In expectation of a clear sky, I had purposed availing myself of the ample leisure I should "have enjoyed, to watch the shadow of the eclipse, to study the corona with the view of making sketches "subsequently and in fact to examine and note all that appeared; but the presence of the mist made it "essential that I should devote my attention entirely to the duty of exposing. It was also plain, that "under existing circumstances, the programme detailed in para. (5) should not be adhered to, and I resolved "to act to the best of my judgement in the matter.

(11.) "As totality approached I was surprised while looking at the sun to find an apparent "absence of all mist; this however was by no means real, for the fog appeared plainly, driving over us as

† Mr. Willis volunteered his services for the occasion and performed his part with every desirable skill and accuracy.

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" before, when I directed my view some 10° below the sun. I accordingly kept a steady watch in this " direction during the periods of exposure, and I am thus able to state with certainty, that throughout " totality the mist was driving over us in one continued and generally diminishing stream, which varied in " density but which was always plainly visible. Watching the mist in this manner and guided by its " density in regulating the exposures, I opened and closed the lens for negatives Nos. 1 to 4, so that the " durations of these exposures are by no means comparable. Subsequently I resolved to make the longest " exposure that could then be afforded, preceding this by one of 5 seconds. This lead to Nos. 5 and 6, " the latter of which was barely within the limit of totality. The times and periods of exposure, the " former reckoned from commencement of counting are as follows :—

					Duration.
Negative No. 1.	was exposed	4ˢ to 19ˢ	from commencement of reckoning (*i.e.* totality nearly.)		15ˢ
Ditto	2.	do.	34 to 44	ditto	ditto	10
Ditto	3.	do.	55 to 63	ditto	ditto	8
Ditto	4.	do.	74 to 80	ditto	ditto	6
Ditto	5.	do.	88 to 93	ditto	ditto	5
Ditto	6.	do.	103 to 123	ditto	ditto	20

" I estimate that when Mr. Willis counted 1, the totality had lasted $\frac{3}{4}$ second, hence approximately the " duration of totality was about 122 seconds.

(12.) " It is hardly necessary to add that I accompanied Captain Waterhouse into the dark room, " or that I anxiously looked on while he developed the negatives with his usual skill and care. The " addition however enables me to offer my testimony of the fact that the negatives were all fully developed, " and this may be desirable in presence of the circumstance that the *longest* exposed negative No. 6 " exhibits the *least* details of the corona ; a deficiency which is most nearly approached in No. 5 which had " the shortest exposure : moreover during the exposures of Nos. 5 and 6 the mist was least dense. I may " here add for what it is worth, that so far as I can conjecture 8 seconds exposure would have been ample " at our station had a clear sky prevailed.

(13.) " Though as already stated I was deterred from looking steadfastly at the appearance of the " eclipsed sun, I yet took every opportunity of glancing at it and did so for perhaps 2 or 3 seconds at " a time. Thus viewed, the general outline of the corona looked like a sand glass or figure 8, in which com- " parisons the 2 re-entering angles must be understood as exaggerated much beyond the reality. There " were no conspicuous prominences ; but of these visible, the ones about the vertex were the strongest I " saw no rays or streamers stretching greatly beyond the moon, and so far as I could estimate, the entire " phenomena of the corona were included within an annulus of half the moon's diameter around her edge. " In brief, what I remembered to have seen during totality is exhibited in the negatives Nos. 1 to 4. They " contain details of which I was unconscious, but I am not aware that they are deficient in any respect.

(14.) " Before parting with the set of six negatives I examined them as closely as the dull light of " a cloudly afternoon would permit, and I was naturally struck by the close resemblance they bore to one " another, for I had been led to expect that the corona shifted from side to side, or at least that certain " of its features altered considerably in some way with the moon's progress. This progress certainly does " not produce any readily apparent change in the corona ; nor yet are the rays most abundant in the " radial prolongation of the prominences ; in fact a prominence is visible almost exactly under each " angle of the two main rifts, which rifts are nearly North and South. As to the rifts they exist only in " the absence of rays. Thus the two main rifts are outlined by the termination of rays, which just at the " re-entering angles where they are shortest, jut out some 5 or 6 minutes from the moon's edge. The " longest rays appear beyond the lower limb, and there they are full 18 minutes or more in length. In general " the rays are radial from some point in the eclipsed body, unless a possible bundle in, I think, the lower " and right hand corner is an exception. The tips of these rays present the curious appearance of a sheaf " of corn when its ears are blown over by the wind.

(15.) " Apart from the local examination which no doubt each set of negatives will undergo, it " appears highly desirable that all the sets taken at Baikul, Avamshy, Ceylon, Australia, Dodabetta, &c, " should be collected together and compared by competent examiners ; it need hardly be added that such " comparison should be made between the negatives and not between prints, for the latter cannot be relied " on as sufficiently exact representations of their originals. The Baikul and Dodabetta negatives were taken " with similar instruments and will therefore readily admit of comparison ; it will be interesting to enquire " whether the latter negatives, taken at a considerable height differ in any respects from all the other " sets. Colonel Tennant's method of mounting will secure the negatives from ordinary risks."

*Extracts from Colonel Tennant's letter to Dr. Huggins.**

"Now to the photographs. We have had some glorious mornings. Yesterday Herschel and "I were up at η *Argûs*, but had no great amount of examination, as our intention was to focus slit, " &c. on stars. Though the evenings have been misty, at times the mornings have been very clear, " and we hoped they would remain so. Last night was very clear, and continued so till about 2ʰ 30ᵐ " a. m., when it became cloudy, and afterwards rained slightly. By the time for getting up it was less

* Monthly Notices of the Royal Astronomical Society Vol. XXXII. No. 3. January 1872.

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"thick, and rain had ceased, but a wind had sprung up from the S.E. (I believe), which, of course, "kept a driving mist on the hill. The Sun seemed to lose as much power by obscuration as it gained "by rising, and was powerless to disperse this as it would otherwise have done, and our instruments "were *dripping*. This I had thought possible in such a case, but I had hoped that the fine weather had "set in, as such mist seems abnormal so late in the season. Very few minutes after totality the mist "vanished from the returning heat.

"Under these circumstances one might have thought photographs hopeless, and I went despond-"ingly to ask for results. I found, to my great astonishment, that they had six apparently good ones, "which is due to Hennessey, who exposed, having thrown over our programme, and increased his ex-"posures, while Captain Waterhouse, who did the photographer's part ably, backed him by rapidly "changing the slides."

Extracts from Colonel Tennant's report to Government.

"From the original photographs Captain Waterhouse has made some positive transparencies on "glass which give a good general idea of them. I take, however, the following descriptions from the "original negatives, some of which give a great deal of detail which is lost in copying.

"No. 1 is perhaps the most perfect. It had an exposure of 15 seconds near the commencement "of the eclipse. I have found that the middle of the eclipse was at 14h. 27m. 4s. Greenwich mean time "according to the tables. Mr. Hennessey, who had most facilities for marking the duration of totality, "gives it as a little more than 122 seconds. From these data, and the reckoning formerly given, I "reckon that this plate was exposed from 14h. 24m. 7s. to 14h. 26m. 22s. of Greenwich mean time. "The disk of the moon is surrounded by a narrow, very luminous border almost indistinguishable from "the prominences, but whose inner edge is sharply defined by the moon, except in one or two places, and "whose outer one varies very much in distance from this, and is much less sharply defined. There is "much encroachment of light on the dark surface of the moon, and this is greatest at the places of "prominences, and especially at the lower part of the disc where the solar edge is nearest. Here the "encroachment nearly obliterates the disc in some places, and presents a very marked outline; here, too, "the brilliant band is brightest and widest, and its outer edge most defined. Outside this is the corona, "at the bottom are seen several rays with ill-defined edges. One of these to the right (S) of lowest "point is markedly curved; the outer end pointing S. W. The great rift to the south, and a less marked "one to the north, each have a prominence at the base;—close to the vertex is seen the small rift which "was spectroscopically examined. There is structure clearly seen in the whole of the corona, and, "except in the case of the curved ray of which I have spoken, it seems to me that there is a tendency "to radiate from prominences. Some of the longest rays may be faintly traced to a distance of $\frac{1}{4}$ths of "the moon's diameter.

"No. 2.—It is evident, on looking at this, that the chemical action has been much less: the "encroachment of the general light on the lunar disc is much reduced, while that of the prominences is "more conspicuous. The broad band of light at the bottom of No. 1 giving an appearance of a well "defined portion of corona has disappeared, and the light now decreases gradually from the moon's edge. "The outline of the lower edge of the south rift is shown as more curved; but comparison shows that "this is not so much a real change of form, as the result of the fainter portions being less depicted. The "*radial structure of the corona is as marked here as in the last photograph, and the same tendency to* "stream from prominences may be recognized with perhaps more facility. The exposure may be con-"sidered to have lasted from 14h. 26m. 37s. to 14h. 26m. 47s. of Greenwich mean time. There is a "good deal of fog about the plate.

"No. 3.—Here the active effects are evidently between those in Nos. 1 and 2; the outline of the "south rift is restored very much to its appearance in No. 1; and the photograph otherwise requires "little remark. It may be considered to have been exposed from 14h. 26m, 58s. to 14h. 26m. 6s. of "Greenwich mean time.

"No. 4 is a good deal like No. 2, save that the lower prominences, being more covered, the "glare there is much less. Placed on a dark ground, and viewed as positives, these two photographs are "very similar; viewed as transparencies, No. 2 has decidedly more detail and extent. It may be considered "as having been exposed from 14h. 27m. 17s. to 14h. 27m. 23s. of Greenwich mean time.

"No. 5. This has less detail than any of the preceeding photographs, and there is a want of "sharp definition, showing that there was some motion of the camera relative to the object. This may "be due to the action of the clock ceasing, as I have mentioned it did during the exposure of plate 6, "and I am disposed to think it is so, but the short exposure makes the effect small, and leaves this "photograph available as evidence of the general permanence of the corona during totality. It may be "considered as exposed between 14h. 27m. 31s. and 14h. 27m. 36s. Greenwich mean time.

"No. 6.—As I have mentioned before, the clock manifestly ceased acting during this exposure. "Looking at the upper edge one sees the succession in which the peaks of the chromosphere appeared, "and it is evident that a momentary exposure would have sufficed for depicting these" * * * * *

Extracts from Colonel Tennant's Report to Government.. Conclusions.

"Spectroscope and polariscope have so far agreed in assigning a solar origin to the main pheno-"menon of the corona; and, if we examine the photographs, we shall have the same result. It is quite

Total Eclipse of the Sun. December 11-12, 1872.

"impossible not to connect the south prominence with the corresponding rift, at whose base it lies, and "whose sides clearly in a general way radiate from it. A comparison of No. 1, and the later photo- "graphs, shows that the connection lasted, and that in fact, the moon passed over the corona. Nos. 1 "and 3 do not show any changes in the forms and positions of the portions of the corona, and an "examination of the later photographs, Nos. 4 and 5, though the definition is not so perfect, quite "supports this. That on the true solar corona is superposed an atmospheric phenomenon is probable "enough; but, as I said in 1868, the corona is solar. It is the atmosphere of the sun in its colder parts. "It is, indeed, to some extent self-luminous, but *mainly* it shines, as I reported in 1868, by reflected "light."

* * * * * * * * *

"The following, then, seems to be the constitution of our sun. There is a nucleus which gives out "continuous white light like solid or liquid bodies, and even dense gases: surrounding this is a layer of "heavy vapors intensely heated, but far less so than the nucleus; in which, if a state of equilibrium could "exist, the heavier vapors would be lowest. Above this is a layer of glowing hydrogen of very slight "density accompanied by that gas which gives the line D_3. Still further up these gases in a cooler state "become mixed with what gives out the green line K 1474, and lastly, that alone seems to remain.

"Of the solar nucleus we know little certainly, possibly we never shall know much, as it is "almost hidden from our view, but we do know that its temperature is so high that we have reason to "believe that unless subjected to enormous pressure every terrestrial element would be vaporized. "It has been estimated in millions of degrees, but such statements can convey no intelligible idea. We "do not know anything of the substance producing the chromospheric line D_3. Professor Respighi's "observations at Podoocotta would go to show that it is inseparable from the hydrogen of the chromo- "sphere. The substance, however, producing the green line K 1474, is one of the most interesting. We "not only meet the evidence of its existence in the sun, but when the higher layers of our own atmosphere "are reached we meet, at the great height at which Auroras take place, a substance which gives out a "light apparently identical, and again Angström and Kirchhoff have assigned the power of giving this "line to the vapor of iron. It seems nearly impossible that at the low temperature which we know must "exist in the upper strata of our atmosphere there can possibly be iron vapor. Is it possible that iron "possesses the property of occluding the gas, whose distinctive line is K 1474? If it be so, this gas must "be under ordinary circumstances of temperature and pressure almost immeasurably rare."

MONTHLY Meteorological results taken from the Register kept at the Office of the Superintendent G. T. Survey of India, Dehra Dun.

YEAR & MONTH.	BAROMETER.						HYGROMETER.				THERMOMETER.						WIND.		CLOUD.		RAIN.	
	h. m. At 9 30 A. M.			h. m. At 3 30 P. M.			h. m. At 9 30 A. M.		h. m. At 3 30 P. M.		Dry Bulb.				Wet Bulb.				h. m. At 9 30 A. M.	h. m. At 3 30 P. M.		
	Highest.	Lowest.	Monthly Mean.	Highest.	Lowest.	Monthly Mean.	Monthly Mean Temperature of Dew point.	Monthly Mean Humidity.	Monthly Mean Temperature of Dew point.	Monthly Mean Humidity.	Max: in Sun's rays.	Min: on Grass.	Max: in Air.	Min: in Air.	Mean in Air.	Max: Wet.	Min: Wet.	Mean Wet.	Average direction.	Mean force in lbs per sq. foot.			No. of days it fell.	Fall in inches.
1871																								
January	27·852	27·681	27·774	27·769	27·629	27·689	44·5	·677	45·2	·416	85·5	30·0	75·2	35·6	55·7	61·8	33·0	48·9	W.	·00	2	3	3	·16
February	·849	·614	·719	·763	·505	·630	49·6	·664	49·3	·455	90·1	39·6	79·7	43·4	62·0	66·7	39·5	53·1	S. E.	·00	4	5	7	2·51
March	·751	·555	·661	·657	·457	·577	47·7	·456	47·1	·313	101·4	40·2	90·0	44·5	67·3	69·0	36·1	52·7	W.	·00	2	3	0	·00
April	·705	·536	·609	·587	·417	·515	57·0	·412	56·4	·262	108·2	49·8	94·7	54·5	76·3	71·2	45·8	58·9	S. W.	·01	3	4	4	·43
May	·657	·374	·528	·513	·243	·432	63·6	·515	61·6	·296	110·5	56·8	96·9	60·5	79·3	78·4	48·7	67·8	"	·01	4	6	14	3·74
June	·541	·241	·388	·436	·183	·306	71·5	·823	75·9	·713	109·6	66·7	96·8	66·8	81·5	83·2	65·7	74·1	N. E. & S.	·00	9	7	24	24·34
July	·520	·163	·370	·470	·189	·311	75·7	·869	75·9	·859	103·5	69·8	89·0	70·7	79·6	81·2	59·8	71·6	N.	·00	8	9	29	36·32
August	·589	·343	·439	·488	·309	·373	74·5	·895	76·0	·814	103·2	69·3	89·9	70·4	79·0	81·2	67·9	71·3	"	·00	9	8	28	38·39
September	·652	·430	·537	·562	·296	·435	72·5	·805	73·0	·745	101·2	61·8	89·2	65·1	78·3	79·6	60·8	72·5	N. & W.	·00	5	5	18	11·03
October	·801	·551	·672	·692	·476	·578	58·4	·582	60·0	·479	99·9	47·9	86·1	53·1	71·7	73·7	43·2	59·5	N. W.	·00	0	0	0	·00
November	·864	·677	·787	·783	·582	·691	48·4	·514	48·3	·399	91·9	36·0	81·4	40·8	63·8	66·4	33·7	52·0	N.	·00	1	1	0	·00
December	28·016	·700	·842	·851	·618	·749	44·9	·653	46·9	·498	80·3	28·3	77·2	41·1	58·0	60·3	34·2	47·8	W.	·00	3	4	3	1·32

ABSTRACT OF RAIN-FALL AT DEHRA DUN G. T. SURVEY OFFICE FROM 1861 TO 1871.

MONTH.	1861. Inches.	1862. Inches.	1863. Inches.	1864. Inches.	1865. Inches.	1866. Inches.	1867. Inches.	1868. Inches.	1869. Inches.	1870. Inches.	1871. Inches.
January.	———	———	3·31	·36	1·03	———	1·25	2·69	1·67	·04	·46
February, ...	———	———	·00	2·18	6·18	———	1·46	7·28	1·43	1·39	2·54
March, ...	———	———	1·69	·52	4·67	———	1·13	1·74	7·25	4·13	·00
April, ...	———	———	·33	·21	1·35	2·50	·74	·84	·11	1·84	·43
May, ...	———	———	·34	2·53	6·15	———	3·21	·82	·00	·31	3·44
June, ...	12·19	———	12·19	·29	2·10	8·21	9·94	6·83	2·96	7·04	24·34
July, ...	24·53	28·66	36·96	37·60	19·12	34·75	28·69	21·26	20·66	33·05	36·32
August, ...	54·75	45·22	24·78	22·59	29·40	23·70	23·63	12·85	16·79	28·45	38·39
September, ...	9·31	20·20	2·19	7·21	10·06	5·60	3·81	3·02	22·56	13·78	11·03
October, ...	·02	5·52	·60	1·68	·00	·20	·93	·05	2·39	1·39	·00
November, ...	·01	·00	·92	·17	·00	———	·00	·00	·00	·00	·00
December, ...	·00	·00	·60	·03	4·02	———	·00	·18	1·22	·01	1·32
Total, ...	100·81	99·60	83·91	75·37	85·58	74·96	75·09	57·56	77·04	91·43	118·27

NOTE.—Where blanks occur no record is forthcoming. Height of Barometer Cistern above Mean Sea Level, 2232·41 feet.

Annual Return of amount of Work executed in the Drawing Branch of the Office of Superintendent G. T. Survey, from 1st May 1871 to 30th April 1872.

Description of Work.	Remarks.
Sheet No. 9 of Levels in the N.W. Provinces (Compilation). *Vide Annual Return for* 1870-71,	For Photo-zincography.
Do. No. 11 ditto ditto ditto ditto, ...	ditto.
Do. No. 14 ditto ditto ditto ditto, ...	ditto.
Do. No. 15 ditto ditto ditto ditto, ...	ditto.
Do. No. 1 Preliminary Chart of the Great Indus Series, ...	ditto.
Do. No. 2 ditto ditto ditto ...	ditto.
Do. No. 3 ditto ditto ditto ...	ditto.
Do. No. 11 ditto ditto ditto ...	ditto.
Do. No. 12 ditto ditto ditto ...	ditto.
Do. No. 1 ditto ditto of the Kashmír Series.	ditto.
Do. No. 4 ditto ditto ditto, ...	ditto.
Do. No. 5 ditto ditto ditto, ...	ditto.
Do. No. 5 ditto of Triangulation in the Northern Portions of the *Bombay Presidency examined and passed. *Vide Annual Return for* 1870-71,	ditto.
Do. No. 6 ditto ditto ditto ditto, ...	ditto.
Do. No. 8 ditto ditto ditto	ditto.
Do. No. 1 ditto of the *Sutlej Series, ...	ditto.
Do. No. 2 ditto ditto, ...	ditto.
Do. No. 3 ditto ditto, ...	ditto.
Do. No. 4 ditto ditto, ...	ditto.
Preliminary Chart of the Jogí-Tíla Series,—Minor Triangulation along Rávi and Chináb Rivers, ...	ditto.
Do. of the North-West Himalaya Series, Season 1850-51, ...	ditto.
Do. of the Bider Longitudinal Series, Season 1869-70, ...	ditto.
Do. ditto ditto Season 1870-71, ...	ditto.
Do. of the Gurhágarh Meridional Series, Seasons 1858-60, ...	ditto.
Do. of the Rahún Meridional Series, Season 1856-57, ...	ditto.
Do. of the Pesháwar and Khágán Triangulation, ...	ditto.
Do. of the Assám Valley Triangulation, Season 1870-71, ...	ditto.
Prepared a Chart of the Násik Triangulation between Lat. 19° 30′ and 20° 30′, and Long. 73° 30′ and 74° 30′, ...	For Computing Office use.
Do. an Extract from the Preliminary Chart of the Great Arc Series Northern Section,	ditto.
Do. an Extract from Khanpisúra Series between the parallels of 20° and 22°,	ditto.
Do. Sheet No. 1 Map of Routes in Northern India (Compilation), Scale 1 inch = 16 miles, Lat. 33° to 38°, Long. 68° to 76°,	For Photo-zincography.
Do. do. No. 2 ditto ditto „ 33° to 38° „ 76° to 84°, ...	ditto.
Do. do. No. 3 ditto ditto „ 28° to 33° „ 68° to 76°, ...	ditto.
Do. Rough Skeleton plan of the town of Mangalur, ...	For Major Branfill.
Do. Route Map from Panjáb to Badukshán, Scale 1 inch = 16 miles, ...	For reduction by Photography.
Do. a trace of the Chamba Territory (on linen) with hills, Scale 1 inch = 2 miles,	For Photo-zincography.
Do. a trace of the Biláspur Meridional Series, ...	For use of Bider Longitudinal Series party.
Do. a trace of Minor Triangulation extending over the Nílgirí and Kundar Mountains (on linen), ...	For Computing Office use.
Do. a trace of triangles extending over portion of province of *Coimbator, ...	ditto.
Do. small Chart illustrating Spirit-Levelling operations section VIII, season 1870-71, scale 1 inch = 20 miles, ...	For Photo-zincography.
Do. Index to the Level Sheets, scale 1 inch = 32 miles, ...	ditto.
Do. General Skeleton Map of Dehli, scale 1 inch = 16 miles, ...	ditto.
Do. Map of the Country round Dehli, scale 1 inch = 2 miles, ...	ditto.
Do. Plan of the battle of Dehli in 1803, ...	ditto.
Do. Plan of the City of Dehli, ...	ditto.
Do. Plan shewing the position of British army before Dehli from June 8th to September 14th 1857, ...	ditto.
Do. Trans-Frontier Map No. 2 (compilation), scale 1 inch=16 miles, between Lat. 34° and 39° 30′ and Longitude 73° and 82°, ...	ditto.
Do. a copy of the ground plan and plan in elevation of the G. T. Survey Office Dehra Dun, ...	For Office use.
Reduced and incorporated additional triangulation in 3 copies of the G. T. Survey Index Chart for its completion to 1st May 1871, ...	To be engraved.
Examined proofs of Preliminary Charts, Maps &c., and other miscellaneous duties, ...	
Colored 4,703 copies of Maps of various kinds, ...	

ayan Explorations for 1871, by Major T. G. y Superintendent G. T. Survey, in charge imalayan Exploring Parties.

selected for this year's report have been made by explor- dition: it is not expedient to refer to him in any way that ny such indications are apt to be conveyed to frontier places, t inconvenience to the explorers by obliging them to start occasionally have hindered them when far beyond the frontier r frontiers.

rtion of his work, made his way from Dárjiling, passing through not however necessary to refer to his journey in detail until he Hooker called the Wallangchoon pass, as up to that point Sir s an admirable description of the country.

ying to pass into Tibet, was as usual stopped and told that he would farther, as he was not known to any one, nor able to give any satis- being what he stated. He was consequently rather in despair, but to ingratiate himself with the chief official of a large Sikkim district to be very ill. I have always made my explorers take a supply of medicines of native kinds, with only a few ordinary European sorts to present to people . In the present instance the explorer had also provided himself with a Hindi treatise as to using these drugs, and when he heard of the woman's illness he her some medicine if he was allowed to see her and hear as to her sufferings &c., s at once accepted and the explorer having seen her searched his book until he came ne disease with the same symptoms as she had and he then boldly prepared the medi- rected and gave them to the woman according to the instructions, and awaited the result a little trepidation. In a few days time the woman became wonderfully better and ually a cure was effected very much to the astonishment of the amateur practitioner. The plorer was treated with marked kindness and hospitality from the day the woman began to improve; he then again urged his request to be allowed to pass into Tibet. The headman said he would be glad to give him permission but that it would be of no use as he would be again stopped by another official before he advanced very far unless he had some one to answer for him. The explorer however continued to urge his point and at last the official said he would himself be his security, and he finally sent one of his own men with the explorer who passed him through the places where he was likely to be stopped.

The explorer consequently marched on without any farther interruption, except the ordinary ones at custom houses, where his baggage was strictly searched; fortunately his instruments were so well concealed that they were never discovered.

From the Tipta-La—the Wallangchoon pass of Sir William Hooker, probably so named from the village south of it, which the explorer gives as Wallungsum—he made his way in two marches to Tashirak. The road was a difficult one, the ground north of the pass being very elevated and barren, so that both food and fuel had to be carried on yáks for the use of the party.

The Tipta-La was covered with snow; it is on the watershed of a very high range that runs nearly east and west forming the boundary between Nepal and Lhása.

Tashirak is a large standing Bhotia encampment on a feeder of the Arun river, which rises in a glacier to the west, and not on the main stream of that river as was formerly supposed; it is 15,000 feet above the sea. Marching north, the explorer crossed the Nila-La pass, and passing a large Láma monastery reached the Shara village of some 50 houses, which is under a Thánahdár of the Tinki or Tinka district, generally known as Tinkijong after its fort (jong). Here his baggage was very closely searched, and it was only by means of the man sent by the Sikkim official that he was able to advance farther. After many inquiries were made he got a pass to travel to Shigatze, and being fairly in Tibet he was never stopped again. He made his way first to Lámádong, a village of 50 or 60 houses, arriving there on the 4th September. Before reaching this place the explorer had latterly seen no cultivation except that of Indian-corn in small quantities, but at Lámádong itself there was a good deal of wheat and pease and round about several other villages could be seen equally well cultivated; all these villages were on or near the banks of the great eastern branch of the Arun river, called the Khantongiri river, which comes from the east.

The next day he arrived at another small vill
to show that he had again reached a warmer climate,

On the 6th September he crossed the Tinki-La
the village of Tasichirang on the bank of the Chomto D
about 20 mil
A large Tibetan Lake.
at an elevatio
lake has never been shown in any map that I am a
existence in itineraries collected by Mr. Hodgson, Dr.
the water very clear and pure, and very good to drink:
told that the inhabitants took it in preference to that
were seen to run into the lake. The explorer was unable t
could see it fully as he passed along its northern shore a
an outlet; the inhabitants declare that it has none: the sweet
against there being no outlet and if so it must be somewhe
forms a portion of the boundary between Sikkim and the Lh
Territory lying to the east, that of Lhása to the west of the lake.
were visible from the lake to the east and south.

On the 7th September he arrived at Ningzi, a Sikkim village
50 houses, boasts of a wonderful number of dogs, the explorer declarin
200, and was certain that he never met with such a large proportion in
they are proverbially numerous.

On the 9th September he reached Chajong (or Tatápáni) hot spri
latitude and thermometer observations, the latter making it 15,000 feet abo
reservoirs, each about 30 feet in circumference and 3 feet deep, have been buil
water of these springs which appeared to be sulphurous and have a high reputat
curative properties, being visited by numbers of people. The place swarmed wi
(Hodgsonian) antelope which are quite tame being never disturbed, as they are consid
dedicated to the deity of these hot springs. The next day the party encamped in a ra
the day after crossed the Lagulung-La pass which has quantities of glacier ice close down
being itself 16,200 feet above the sea. This pass forms the boundary between Sikkim
Lhása, the march terminated at the village of Thak. On the 15th September he passed the v
lage and part of Sai Jong which is surrounded by cultivation and has numerous other villages
round about, encamped at Chota-Tápu or Darcha village on the banks of the Sai Jong stream,
which comes from a great distance, rising in Sikkim. The next day crossed the Gyaling moun-
tains by a pass covered with snow, and reached the Bálu Koti village of 20 houses; this
place has a good deal of cultivation, and numerous other villages are visible round about it.
Passing thence through a level and well cultivated country, the explorer reached Shigatze on
the 17th of September.

The explorer paid the usual homage to the Láma of Tashi Lambo, making an offering of
two rupees. He found the city of Shigatze in much the same state as described by the chief Pan-
dit, he however heard of the serious rebellion which had been raised against the great Láma of
Lhása in April 1871, during which hundreds of people were killed.

The explorer remained in Shigatze till the 29th of September, he then made his way
south-westwards, towards the Dingri maidán, resuming his route survey on the 30th September
from a point he had previously visited. By evening he reached the village of Shimrang and the
next day crossed the Shabki-Chu river which was 65 paces wide and 4 feet deep, flowing down in-
to the Sang-po (Bráhmáputra), numbers of villages were seen on and off the road. The harvest
was being reaped.

On the 2nd of October he reached the great Shakia monastery (*Gonpa*) which is only
second to that of Tashi Lambo. The explorer was unfortunately not able to stop at Shakia to
examine the place more closely. He says the Shakia monastery is on a low spur, it is inhabited
by about 2,500 monk Lámás, ruled by a great Láma called Shakia-Gangma (king or above all
others); he is looked upon as a deity. His Lámás are the only ones in this part of Tibet that
are allowed to marry, they are called *Dhukpás*, other Lámás who are not allowed to marry being
called *Gálupás*. The town of Shakia lies at the foot of the monastery and is about half the size
of the city of Shigatze. About fifty of the shops in the town are kept by Niwars from Nepal,
all the other shops are kept by Bhotias. There is a large amount of cultivation around Shakia
though it is about 13,900 feet above the sea.

On the 3rd of October the explorer crossed the Dongo-La feet above sea, and again
got into ground drained by the Arun river, and on the 5th October reached the Chokuar village,
on the left bank of the Phungtu or Dingri-Chu river, the great western branch of the Arun river.

-Chu river, the explorer reached the Sakar-Chu
r-jong (fort) is about 8 miles north of the junc-
trate. The Ghurkas in 1854 advanced as far as

er reached the town of Dingri which is generally
open plain in which it stands, it is also sometimes
250 houses supplemented with tents on occasions of

the Shakar-Chu river, the explorer crossed the Dingri-
es in length. Showing that even at that point this great
large stream as might be expected from its draining

e Dingri town stands the Dingri Khar (fort) on a low
officer called a *Daipon* who is the chief military and civil
as a small garrison of Bhotia soldiers with but one gun.

very good road which runs north-east to Jong-ka-Jong and
atmándu. Officials are however the only persons who are allowed
ers and all others taking the one followed by the explorer to

not make any stay in Dingri, being afraid that he might be cut off
y fall of snow, he accordingly pushed on as fast as he could. At first he
de all but level tract, and then getting into rougher ground reached the
n the 10th of October; he found the pass covered with old ice and snow, it
t above the sea.

e 11th October he reached the town of Nilam 13,900 feet above the sea which
250 houses. It is ruled by a couple of *Jongpons*, the Lhása Government sending
so as to be a check on one another. Nilam being the first Tibetan town on the road
epal, is considered to demand extra vigilance and consequently the explorer and his
were very closely examined and their baggage was carefully searched before they were
owed to go on.

From Shigatze to the Thung-lung-La pass, the explorer had passed through a moderately level tract though at a very great elevation, but from the Thung-lung-La, where he crossed the Himalayan watershed he again entered on very rugged ground much more difficult than even that south of the Tipta-La (or Wallungsum pass).

Between Nilam and Listi Bhansár he followed the general course of the Bhotia-Kosi river, and though it is but some 25 miles direct distance between the two places, the explorer had to cross the Bhotia-Kosi river 15 times by means of 3 iron suspension, and 11 wooden bridges each of from 24 to 60 paces in length. At one place the river ran in a gigantic chasm the sides of which were so close to one another, that a bridge of 24 paces was sufficient to span it. This was just below or south of the village of Choksum. Near this bridge the precipices were so impracticable that the path had of necessity to be supported on iron pegs let into the face of the rock. The path being formed by bars of iron and slabs of stone stretching from peg to peg and covered with earth. This extraordinary path is in no place more than 18 inches and often not more than nine inches in width, and is carried for more than one-third of a mile (775 paces) along the face of the cliff, at some 1,500 feet above the river which could be seen roaring below in its narrow bed. The explorer who has seen much difficult ground in the Himalayas, says he never in his life met with any thing to equal this bit of path. It is of course quite impassable for ponies or yáks, and but very few sheep and goats even go by it though it is constantly passed by men with loads.

There are several other smaller pieces of paths between Nilam and Listi Bhansár which are nearly as bad but they are fortunately not continuous.

From Listi Bhansár the explorer's route does not call for any special notice here being much the same as that in any other part of the mountains south of the Himalayan watershed, being rugged in the extreme for a considerable distance and then becoming easy in the valleys or Dúns. It may however be noted that the explorer crossed the Indrawati feeder of the Kosi which has 5 small tarns near its source called Panch Pokri. The source is in the snowy mountains to the west as shown on the map.

The lower ground, though not at all not
any way previously, the only land marks being
that have been fixed from a distance by the Great
consider the survey of it and other portions of the
the geography of that part of the mountains.

On reference to the map it will be seen that
great Himalayan watershed has been determined in
proves to be far behind or north of the lofty peaks th
Mount Everest, Kanchinjinga, &c.

The explorer it will be seen went completely round
so hemmed in by great mountains that he never got a view
to have been invariably hidden by the subordinate peak
Possibly it may have been seen but never continuously so a
and to fix it by bearings with a moderately long base. The
were, however, seen from the west of Taplang Jong but only
The explorer was much impressed by Kanchinjinga (28,150 feet
near Taplang as *Kumbh Karan Langúr*. The people south of t
all snowy mountains *Langúr*, by which they mean the highest
that have no snow *Banjung* and the low ground under the said *Ban*
term Himalayas is not used by uneducated people who only talk o
"*Barfáni Langúr.*"

Neither the Bhotias nor the Ghurkas seem to have specific n
peaks; the explorer asked all sorts of people but with the exception of the
referred to above, he never got any name for a peak, though in a few cases
the nearest village.

Several of the other peaks fixed by the explorer were very lofty ones covered
petual snow to a great distance below their summits, those north of Mount Everest
chinjinga are perhaps the most interesting as being beyond the Himalayan watershed.
the north of the road between Shakia and Dingri, the explorer thought was very much
than any others.

The explorer's route survey may be said in a rough way to give us a general idea as to how the mountain drainage runs between the Himalayan watershed, north-west of Kirong, and the point where Turner crossed it near Chumalári up to the Brálmáputra, or Sang-po river on the north from west of Junglache to Shigatze. The route between Kirong, Jong-ka-Jong, and Dingri Maidán is still a desideratum as we are in the dark as to the size of the Palgucho lake, which however it now appears will lie somewhat to the south of the approximate position which I gave it in my map showing the chief Pandit's route to Lhása.

A glance at the map at once shows what a large river the Arun must be, the area it drains being so very great. It is one of the few Himalayan rivers which has its source beyond the Himalayan range as seen from Hindustán, the others being the Indus, Sutlej and Karnáli. The length of the eastern and western upper sources is very remarkable, extending on the one side to the north and east of Kanchinjinga, and on the other to the north and west of Mount Everest.

In the route survey made by explorer No. 9 from Dárjiling to Shigatze, and from Shigatze by Shakia, Dingri Maidán, Nilam &c., to Katmándu, the value of his pace has in the first instance been derived from the differences of latitude between the various places at which star observations for latitude were taken. A mean value of pace *viz*; 2.45 feet, derived from a mean of the values of each section, was adopted, and this mean value was applied to the number of paces showing the differences of longitude for each section and the value of the same in degrees and minutes was deduced therefrom in the usual way.

Taking the longitude of Dárjiling at 88° 18′ 41″ as determined by the triangulation of the G. T. Survey, and applying the differences of longitude as determined above, the longitude of Shigatze, by Tatápáni, Chota Tápu, &c., vide map, *i.e.*, by the most direct route would be 88° 46′ 44″.

Taking the longitude of Katmándu at 85° 17′ 45″ and applying the differences of longitude as above between it and Shigatze by Nilam, Dingri, Pil &c., the longitude of Shigatze would be 88° 32′ 45″.

ce apparent the longitude of Shigatze, as
likely to be more reliable than that derived
tude, between Dárjíling and Shigatze, is but
d Shigatze, is 3° 11′, or in other words the
affected by an error in the value of the pace in
sequently decided upon using only the value as

andit's exploration to Lhása, I explain that the
e route survey which Mr. Turner made during
route of the Pandit, Shigatze was computed to be
with the value as determined above independently
consequently be concluded that the longitudes of
igatze, as given in my first map, are very close ap-
hat my reliance on Turner's route survey was not

ll the usual tests satisfactorily, the average value of his
differences in latitude, is about what might be expected
e observations agree very well *inter se* considering that he
s observations at Shigatze give much the same latitude
it's observations with a large sextant at that and other

est part of his work, as owing to the larger thermometers
een broken, he was reduced to take his boiling point observa-
neter. The heights however are probably fair approximations,
the great elevation of the upper part of his ground.

on either side of his road were more numerous than usual, and
uccessful in fixing the more conspicuous.

with its bearings &c., opens out the geography of nearly 30,000 square
itherto been in many portions *terra-incognita* and in others nearly so; the
maps having been of course mostly conjectural. The exploration more espe-
s the geography of the basin of the Arun or Arun-kosi river, the great
, if not the main source of the great Kosi or Kosiki river, which drains the whole
Nepal. The courses of the upper feeders of the Arun have hitherto been a puzzle
graphers. The explorer's work also defines the course of the great western tributary of
Kosi river *viz*, the Bhotia Kosi of which we had previously no survey.

His route survey is 844 miles in length of which 550 miles may be said to be over entirely new ground, and the remainder (though close to a line along which one European has travelled) had never been regularly surveyed before.

The explorer took latitude observations at 11 points upon which the work depends and determined the height of 31 places. His work I think will prove a valuable addition to the Trans-Frontier geography of India.

T. G. MONTGOMERIE, Major R.E.,
Offg. Superintendent G. T. Survey of India,
and in charge Trans-Himalayan Exploring Parties.

6—b

List of positions of the chief places

of explorer No. 9 in

	Latitude				
	°	′			
Dárjiling.	27	2			
Tatápáni.	28	36			
Chota-Tápu (or Darcha village). ..	28	57			
Shigatze (Tashilumbo). ..	29	17	88		
Pil.	28	37	87		
Dingri-Maidán town.	28	35	86		
Nilam-Jong (or Kuti).	28	9	86	5	
Katmándu.	27	41	85	18	
Kabiri River, Bank of.	..	..	87	33	
Narharia (Naria).	26	26	86	45	
Dhankuta.	26	56	87	21	
Lámádong.	27	10	86	52	..
Amtia on bank of Arun River. ..	27	12	87	12	1798

The longitude of Shigatze is derived from Dárjiling by the route survey passing ... Tatápáni and Chota-Tápu. In the map accompanying this memorandum, 88° 40′ was assum... be the longitude, using a mean between the values derived from Katmándu and Shigatz... In future compilations the positions as given on the map, will require to be corrected to those given above.

Observations for Latitudes taken in Ne

No. of Observation.	Astronomical Date.		Watch Time.			Station.	C					
			h	m	s			°				
1	1871. Septr.	11th	12	0	0	Tatápáni.	Fomalhaut.	62 14 30				
2	„	„	13	0	0	„	β Ceti.	85 28 30	„	28 [illegible]		
3	„	12th	12	0	0	„	Fomalhaut.	62 14 0	„	28 35 59		
4	„	„	13	0	0	„	β Ceti.	85 27 0	„	28 35 37		
5	„	15th	12	0	0	Chota-Tápu.	Fomalhaut.	61 32 30	„	28 56 44	28 56 56	Ditto.
6	„	„	13	0	0	„	β Ceti.	84 44 0	„	28 57 8		Ditto.
7	„	28th	12	0	0	Shikache.	Fomalhaut.	60 53 30	„	29 16 14		Ditto.
8	„	„	13	0	0	„	β Ceti.	84 4 0	„	29 17 7		Ditto.
9	„	29th	12	0	0	„	Polaris.	61 23 0	„	29 17 44	29 17 1	Ditto.
10	„	30th	12	0		„	„	61 24 0	„	29 18 16		Ditto.
11	„	„	12	0	0	„	Fomalhaut.	60 54 30	„	29 15 44		Ditto.
12	Octr.	4th	11	0	0	Pil village.	„	62 15 0	„	28 35 26	28 37 16	Ditto.
13	„	„	12	0	0	„	β Ceti.	85 20 0	„	28 39 6		Ditto.
14	„	7th	11	0	0	Dingri Maidán.	Fomalhaut.	62 18 0	„	28 33 55	28 34 30	Ditto.
15	„	„	12	0	0	„	β Ceti.	85 28 0	„	28 35 5		Ditto.

Observations for Latitudes taken in Nepal and Great Tibet.—(Continued.)

No. of Observation.	Astronomical Date.		Watch Time.	STATION.	Object.	Double Altitude.	Index Error.	Declined Latitude.	Mean Latitude.	REMARKS.
	1871		h m s			° ′ ″	′ ″	° ′ ″		
16	October	11th	11 0 0	Nilam or Kuti.	Fomalhaut.	63 4 0	−1 0	28 10 54	° ′ ″ 28 9 24	On Meridian.
17	,,	,,	12 0 0	,,	β Coti.	86 17 0	,,	28 10 34		Ditto.
18	,,	,,	12 0 0	,,	Polaris.	59 1 0	,,	28 6 44		Ditto.
	1872									
19	January	3rd	11 0 0	Katmándu.	Orionis Rigel.	107 50 0	,,	27 44 2	27 43 29	Ditto.
20	,,	,,	12 0 0	,,	Sirius.	91 30 0	,,	27 42 55		Ditto.
21	,,	17th	11 0 0	Lámádong.	Orionis Rigel.	108 58 0	,,	27 10 1	27 1[illegible]	
22	,,	,,	12 0 0	,,	Sirius.	92 35 0	,,	27 10 21		
23	,,	22nd	10 30 0	Amtia village on bank of Arun river.	Orionis Rigel.	108 54 0	,,			
24	,,	,,	11 30 0	,,	Sirius.	92 3[illegible]				
25	,,	29th	10 0 0	Dhankuta Bazar.	Orionis Rigel					
26	,,	,,	11 0 0	,,	Sirius.					
27	February	7th	9 0 0	Narharia Bazar.	Orio[illegible]					
28	,,	,,	10 0 0	,,	[illegible]					

Observations of the Boiling Point taken in Nepal and Great Tibet by Explorer No. 9.

No. of Observation.	Month and date.		Watch time.	Station.	Thermometer. No.	Thermometer. Boiling Point.	Thermometer. In Air.	Deduced Height above Sea in feet.	Remarks.
	1871					°	°		
1	August	1	8 A.M.	Dárjiling	7	201·15	64·25	7,253	West wind.
2	...	...	...	Ditto	10	201·5	„		A point in Dárjiling 7170 by G. T. S.
3	„	5	7 A.M.	Phalialung Lek...	10	195·2	55·2	10,575	No wind and rain.
4	„	...	...	Ditto	7	196·0	„		Ditto.
5	„	7	6 P.M.	Suria Lek	7	198·0	63·0	9,190	South wind and rain.
6	„	9	9 A.M.	Bank of Kabiri river	7	211·0	78·0	1,677	West wind.
7	„	15	8 A.M.	Walungsamgola	10	195·3	60·0	10,564	No wind.
8	„	...	...	Ditto	7	196·0	„		Ditto.
9	„	16	1 P.M.	Tipta-La	7	187·0	46·0	15,618	No wind.
10	„	28	10 A.M.	Tashirak village	7	188·0	47·0	15,025	North wind.
11	September	1	9 A.M.	Shara village	7	190·0	68·0	13,983	Ditto.
12	„	4	3 P.M.	Lámádong thanka	7	191·5	67·0	13,071	Ditto.
13	„	6	7 A.M.	Tashichirang village at bank of Chomto Dong Lake ...	7	188·5	48·0	14,734	East wind.
14	„	12	...	Tatápáni or Chajong	7	188·0	47·0	15,025	Ditto.
15	„	14	11 A.M.	Lagulung-La	7	186·0	44·0	16,201	South wind.
16	„	15	4 P.M.	Chota Tápu or Darcha village...	7	189·0	64·0	14,558	East wind.

NOTE.—Lek signifies a pass.

Observations of the Boiling Point taken in Nepal and Great Tibet by Explorer No. 9—(Continued).

No. of Observation.	Month and date.		Watch time.	Station.	Thermometer. No.	Thermometer. Boiling Point.	Thermometer. In Air.	Deduced Height above Sea in feet.	Remarks.
	1871					°	°		
17	September	19	11 A.M.	Shigatze	7	192·0	61·0	11,822	No wind.
18	„	23	7 A.M.	Ditto.	7	192·5	62·0		East wind.
19	October	3	5 P.M.	Shakia near Tachuk	7	190·0	50·0	13,859	South wind.
20	„	4	7 A.M.	Pil village	7	191·0	49·5	13,259	Ditto.
21	„	9	6 A.M.	Dingri maidán	7	190·0	51·0	13,865	West wind.
22	„	10	8 A.M.	Thung-lung-La	7	182·0	30·0	18,460	South wind.
23	„	13	7 A.M.	Nilam or Kuti	7	190·0	57·0	13,011	Ditto.
24	„	15	5 P.M.	Tata Bhansár	7	205·25	66·0	5,002	No wind.
25	December 1872	7	8 A.M.	Katmándu	7	208·0	...	...	
26	January	8	7 A.M.	Triboni bank of Sun-kosi and Tamba-kosi river	7	...	50·0	...	
27	„	9	6 A.M.	Hilia Lek	7	206·0	46·0	4,620	West wind.
28	„	11	10 A.M.	Kanjia Lek	7	206·0	46·0	4,620	Ditto.
29	„	17	„	Kumdia Lek	7	208·0	43·0	6,302	No wind and rain.
30	„	18	7 A.M.	Lamkhu village...	7	206·0	45·0	4,622	North wind.
31	„	...	2 P.M.	Chakuwa Lek	7	202·0	42·0	6,869	Ditto.
32	„	22	7 A.M.	Amtia V. on bank of Arun river	7	211·0	54·0	1,798	East wind.

Observations of the Boiling Point taken in Nepal and Great Tibet by Explorer No. 9—(Continued).

No. of Observation.	Month and date.		Watch time.	Station.	Thermometer.			Deduced Height above Sea in feet.	Remarks.
					No.	Boiling Point.	In Air.		
	1872.					°	°		
33	January	26	0 P.M.	Chuwa Lek	7		44·0		Data incomplete.
34	„	28	7 A.M.	Sudab village	7	208·0	50·0	3,493	South wind.
35	February	1	9 A.M.	Dhankuta bazar	7	209·0	52·0	2,927	Ditto.
36	„	3	7 A.M.	Barah chotr	7	...	55·0		West wind.
37	„	7	7 P.M.	Naria bazar	7	...	55·0		South wind.
38	June	19	0 P.M.	Masúri G. T. Survey office ...	7	201·75	75·0		
39	August	12	11½ A.M.	Ditto.	7	202·00	70·5		Mean of six. Cloudy and calm.

Note.—The preceding heights above Sea level are computed differentially from height of Masúri observatory taken at 6937 feet to which the observer's boiling point 201·63° and temperature 72·75° have been assumed as corresponding.

Route Survey from Dárjiling (Thánah) to Shigatze (Market Place).

No. of Station.	Name of Station.	Bearing to forward station.	Distance in paces to forward station.	Remarks.
		° ′		
1	Dárjiling ..	294 30	13963	
2	.. ..	275 30	4152	
3	Kainchalia ..	334 30	7279	Thánah.
4	.. ..	285 0	2350	
5	Hamaphong ..	281 30	10340	Village.
6	.. ..	292 0	15100	
7	Phalialung Lek ..	274 0	2871	
8	.. ..	240 0	8100	On boundary between British and Nepal Territories.
9	.. ..	285 0	13010	
10	Nablang ..	297 0	9580	Village.
11	Suriabhanjan ..	320 30	5425	Hill.
12	Suria Lek ..	299 0	7085	,,
13	Shikárpur ..	290 30	15140	Village.
14	Kabiri ..	340 0	4566	Stream.
15	Phuwa Village ..	311 0	13850	200 yards from.
16	Taplang Jong ..	17 30	16807	Village.
17	.. ..	42 0	6608	
18	.. ..	66 30	3859	
19	Tabkia Thok ..	35 0	11150	Village.
20	.. ..	66 0	17097	
21	Ebangkhola ..	301 0	7270	Stream.
22	Tambru ..	11 0	8511	River, on bank of.
23	.. ..	18 30	11800	
24	.. ..	320 0	8010	
25	.. ..	335 0	18001	
26	.. ..	360 0	5938	
27	Tashirak Chu ..	21 0	10200	Stream, on left bank of.
28	.. ..	345 0	12100	
29	Nila-La ..	20 0	9910	Hill, on top of.
30	Shara ..	40 30	34030	Village.
31	.. ..	90 0	4700	
32	.. ..	65 30	28530	
33	Tashichirang ..	270 0	2288	Village.
34	Chomto Dong ..	22 30	2500	Lake, on bank of.
35	.. ..	67 0	21225	
36	Nangji ..	358 0	6065	Village.
37	Chajong ..	67 30	5450	,, Latitude observed.
38	Tinki-La ..	75 0	6684	Hill, on top of.
39	.. ..	35 0	20104	
40	Lagulung-La ..	345 0	11670	Hill. Boundary of Sikkim & Lhása.
41	.. ..	16 30	18194	
42	Ruksum ..	0 0	8955	Stream, on bank of.
43	.. ..	53 0	7715	
44	Chota Tápu ..	26 0	8010	Village. Latitude observed.
45	Gyaling-La ..	67 30	5000	Hill, on top of.
46	.. ..	25 30	6393	
47	.. .	35 30	9600	
48	.. ..	30 0	16896	
49	.. ..	33 30	12000	
50	Shigatze ..	....	....	City. The Market place. Latitude observed.

...om Changma (Village near Shigatze) to Katmándu.

...tion.	Name of Station.	Bearing to forward station.	Distance in paces to forward station.	Remarks.
		° ′		
1	Changma	250 30	14765	Village—10996 paces from station No. 48 on the line from No. 48 to No. 49 of foregoing Numbering.
2	.. ..	252 30	10850	
3	.. ..	235 0	4300	
4	Nangla ..	225 0	15125	Hill, on top of.
5	Sab-Chu ..	280 0	1280	River, on right bank of.
6	Lingbochen ..	175 0	6800	Temple.
7	Puksum ..	235 0	11383	Stream, on bank of.
8	.. ..	212 0	12095	
9	Chong-La ..	266 0	13790	Hill.
10	.. ..	200 0	2500	
11	Ata-La ..	270 30	11350	Hill.
12	.. ..	194 30	6500	
13	.. ..	224 30	7500	
14	Dongo-La ..	212 0	11100	Hill.
15	Simas-Chu ..	183 30	19880	Stream, on bank of.
16	Pil village ..	206 0	13300	Latitude observed.
17	.. ..	230 0	9118	
18	.. ..	215 30	14712	
19	.. ..	280 0	13000	
20	Chaiokor ..	295 30	30760	Village.
21	Phungtu ..	267 0	7600	River, on bank of.
22	Ditto ..	275 0	6500	Do.
23	Ditto ..	270 0	10294	Do.
24	.. ..	250 0	9690	
25	.. ..	265 0	17400	
26	Chakor ..	260 30	25100	Village.
27	.. ..	279 30	11235	
28	Dingri Jong ..	232 0	32016	Town, at entrance to. Latitude observed.
29	.. ..	294 0	6500	
30	Thungla ..	269 30	17181	Hill.
31	.. ..	225 0	8500	
32	.. ..	204 0	7870	
33	Palgu ..	235 30	4050	Stream, on bank of.
34	.. ..	205 0	5820	
35	Thakialing ..	195 30	21921	Village.
36	Nilam Jong ..	210 0	4800	Do. Latitude observed.
37	Kosi River ..	135 0	5170	On right bank of.
38	Ditto ..	190 30	3200	Do.
39	Ditto ..	176 0	3540	On Bridge.
40	Choksum ..	184 30	2870	Village.
41	.. ..	195 30	12197	
42	.. ..	152 0	2775	
43	.. ..	209 0	13017	
44	.. ..	207 0	4045	
45	.. ..	215 0	6182	
46	Kanglank ..	230 0	3800	Hill, on top of.
47	Listi ..	252 0	3325	Do.
48	Listi Village ..	190 30	8725	
49	.. ..	215 0	2600	
50	Bisinkhar Lek ..	255 30	4942	

From Changma (Village near Shigatze) to Katmándu—(Continued)

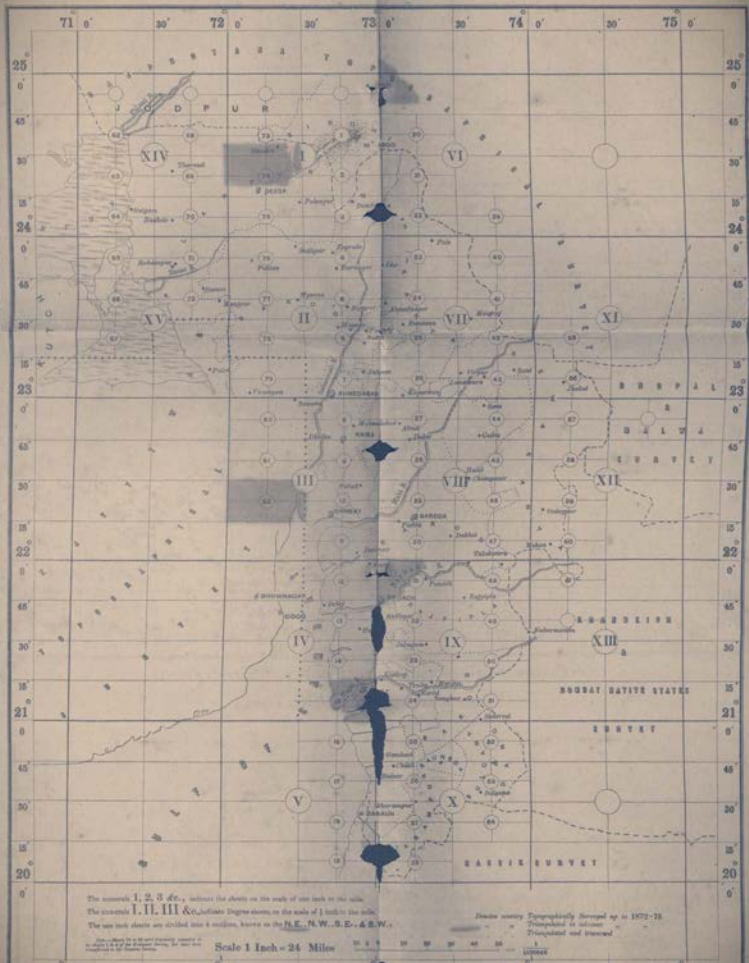
No. of Station.	Name of Station.	Bearing to forward station.	Distance in paces to forward station.	Remarks.
		° ′		
51	.. ..	240 30	5480	
52	Balefi ..	200 0	5470	Stream, on bank of.
53	.. ..	248 30	3210	
54	Banspati ..	241 30	3600	Village.
55	Choutra ..	228 30	3425	Do.
56	.. ..	231 30	5900	
57	Ghetar ..	271 30	3360	Village.
58	Sipa ..	241 30	4065	Do.
59	Jherkola ..	260 30	3826	Stream, on bank of.
60	Dhankola ..	271 30	7100	Do.
61	.. ..	251 0	9310	
62	Chautaria Lek ..	226 0	2300	Hill, on top of.
63	.. ..	221 30	3890	
64	.. ..	270 0	5635	
65	Kalitar ..	252 30	8210	Village.
66	Chabeli ..	225 0	6170	Do.
67	Katmándu ..			At Indar Chaok (centre of city.)

From Katmándu (Asan Tol) to Taplang Jong (Station No. 16 of Route from Dárjiling to Shigatze).

1	Katmándu ..	112 0	7575	Asan Tol. Latitude observed on this line, 1025 paces from starting point.
2	Dimi Village ..	110 0	2250	
3	.. ..	106 0	3710	
4	.. ..	115 0	6,,00	
5	Bist Village ..	109 0	2335	
6	Burapa „ ..	129 0	4060	
7	.. ..	113 30	5660	
8	Nabna Lek ..	126 30	4700	
9	Dabchia Village ..	122 0	3230	
10	. ..	118 30	4850	
11	.. ..	66 30	2500	
12	.. ..	123 30	4415	
13	.. ..	135 30	6825	
14	.. ..	112 0	5200	
15	.. ..	110 0	4910	
16	.. ..	127 0	7800	
17	Jhangajholi ..	105 0	4786	Village.
18	Mulkotar ..	127 30	6400	Do.
19	.. ..	74 0	2415	
20	.. ..	144 0	5500	
21	Tribeni ..	92 0	7200	Junction of two streams.
22	Bedana ..	110 0	3950	Village.
23	.. ..	100 0	5700	
24	Hilia Village ..	32 0	3000	
25	.. ..	35 0	3500	
26	.. ..	112 0	2000	
27	.. ..	60 0	1900	
28	.. ..	93 0	4000	

GREAT TRIGONOMETRICAL SURVEY OF INDIA

INDEX CHART OF THE GUZERAT TOPOGRAPHICAL SURVEY

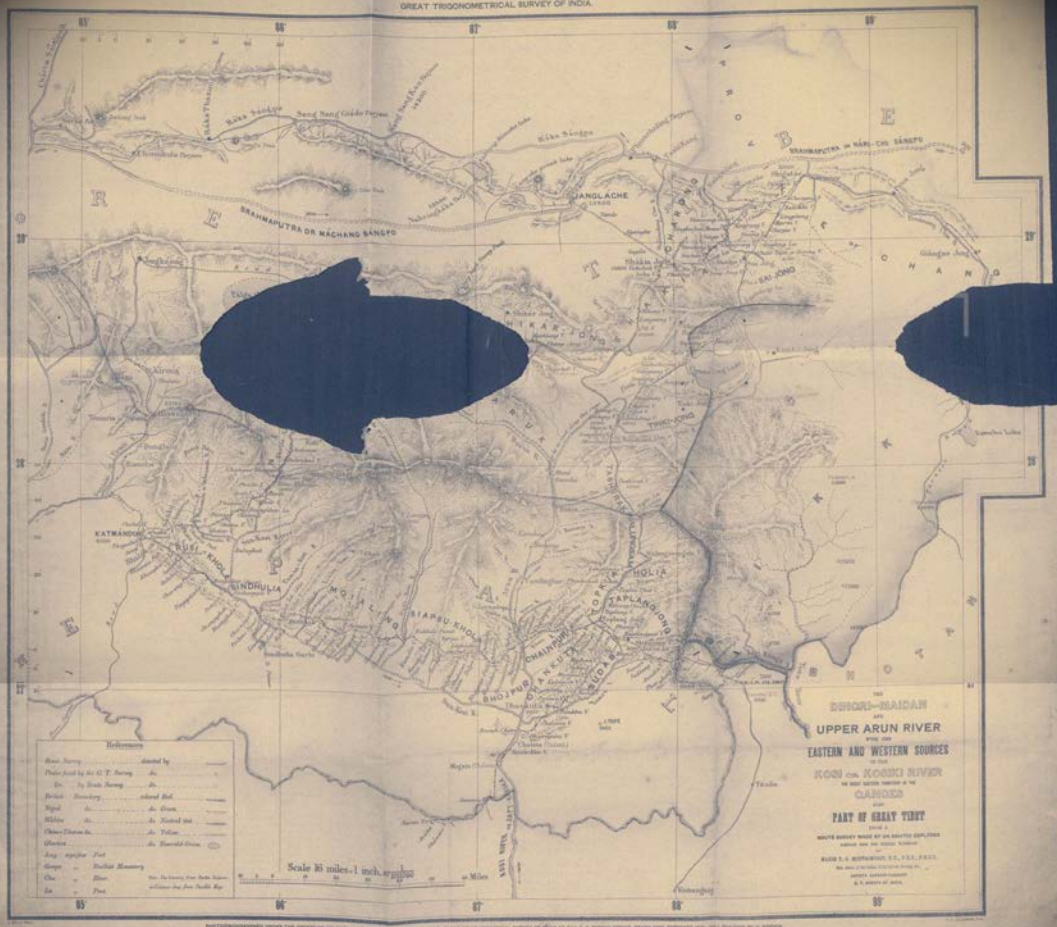


Northern Section.

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

INDEX TO MAIN LEVEL LINES WITH G. T. SURVEY AND COMPILATION OF CHARTS.

Sheet No. 1.



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Northern Section.

INDEX TO MAIN LEVEL LINES OF THE G. T. SURVEY AND COMPILATION OF CHARTS.

Sheet No. 1.

GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1872-73,

Prepared for submission to the Government of India.

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1873.

BAY OF BENG
INDEX CHART
TO THE
GREAT TRIGONOMETRICAL SURVEY
OF
INDIA
CEYLON

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THE OPERATIONS OF THE
GREAT TRIGONOMETRICAL SURVEY OF INDIA

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„	last line	„	Canada	„	Canara.
46—a	line 13 from bottom	„	Singals	„	Signals.
53—a	„ 30 „	„	(9)	„	(10).
56—a	„ 2 from top	„	opon	„	upon
„	„ 28 „	„	singal	„	signal.
„	„ 31 „	„	inturruption	„	interruption.
„	„ 23 from bottom	„	arrange	„	a range.
57—a	para (35) margin	„	Batteries 'relay circuit'	„	Batteries for 'relay circuit'.
„	line 26 from bottom	„	errected	„	erected.
58—a	„ 26 and 27 from top	„	tramission	„	transmission.
„	last line	„	strenth	„	strength.
59—a	line 3 from bottom	*after*	'dots'	*insert*	,
„	„ 2 „	*for*	$\frac{1}{100^s}$	*read*	$\frac{1}{10^s}$.
„	„ 2 „	„	$\frac{1}{10^s}$,	„	$\frac{1}{100^s}$.
61—a	„ 27 „	*after*	+ 0·072	*insert*	,
„	„ 16 „	*for*	Banglore and Manglore	*read*	Bangalore and Mangalore.
„	para (58) margin	*before*	by other observers	*insert*	Ditto.
„	line 3 from bottom			*dele*	already alluded to (para 55).
62—a	„ 6 from top	*for*	varions	*read*	various.
65—a	„ 27 from bottom	„	Jaoria	„	Jooria.
66—a	„ 11 from top	„	secured	„	seemed.
„	„ 22 „	„	attatched	„	attached.
„	„ 31 „	„	interval	„	internal.
„	„ 10 from bottom	„	have screws	„	has a screw.
67—a	„ 8 „	„	good	„	gold.
69—a	„ 31 from top	„	good	„	great.

THE OPERATIONS OF THE
GREAT TRIGONOMETRICAL SURVEY OF INDIA
IN 1872-73.

The following is a summary of the several operations of the present year, given in the order in which they will be found described in this report.

			Described at pages of the Report.	Described at pages of the Appendix.
I.	*Trigonometrical.*	The Biláspur Series, Southern Section, Meridian 82°	6	3—a
II.	*Trigonometrical.*	The Biláspur Series, Northern Section, Meridian 82°	7	8—a
III.	*Trigonometrical.*	The operations in the Assam Valley. ...	7	9—a
IV.	*Trigonometrical.*	The Jodhpúr Series, Meridian 72½°. ...	9	11—a
V.	*Trigonometrical.*	The operations on the Meridian, 75°, and the parallel, 13°, of Mangalore.	10	13—a
VI.	*Trigonometrical.*	The Brahmaputra Series, Meridian 90°. ...	12	20—a
VII.	*Topographical.*	The Survey of Kattywar. ...	13	23—a
VIII.	*Topographical.*	The Survey of Guzerat. ...	14	30—a
IX.	*Topographical.*	Himalayan Surveys in Kumaon and Gurhwal. ...	17	36—a
X.	*Geodetic.*	Electro-telegraphic determinations of difference of longitude in the parallel of 13°.	18	43—a 52—a
XI.	*Geodetic.*	Astronomical determinations of latitude. ...	24	42—a 47—a
XII.	*Geodetic.*	The pendulum operations. ...	25	
XIII.	*Tidal.*	Determinations of mean-sea level. ...	25	65—a
XIV.	*Geographical.*	Trans-Himalayan explorations. ...	29	
XV.	*Computing Office.*	Examination, final reduction and publication of the observations.	30	71—a 77—a
XVI.	*Cartography.*	Preparation and publication of various Charts and Maps.	31	78—a

(2.) The operations carried on during the year under review have produced the following out-turn of work;—of Principal Triangulation, with the great theodolites of the Survey, 92 triangles, covering an area of 11,058 square miles, and disposed in chains which, if united, would extend over a direct length of 416 miles, and in connection with which seven astronomical azimuths of verification have been measured;—of Secondary Triangulation, with smaller theodolites, an area of 3,224 square miles has been closely covered with points for the topographical surveys, an area of 11,532 square miles has been operated in *pari passu* with the principal triangulation, and in an area of 7,290 square miles of a portion of the Himalayas, which is inhabited by independent tribes, several points have been fixed which will be valuable for preliminary geographical requirements;—of Topographical Surveying, an area of 2,734 square miles has been finally completed in the Himalayas, on the scale of one inch to the mile, and an area of 3878 square miles, on the two-inch scale, in portions of the Bombay Presidency, in the course of which 2,734 linear miles of boundary and check lines have been traversed;—and of Geodetic Operations, the amplitude of the arc of parallel between Madras and Mangalore has been determined by the electro-telegraphic method, and the pendulums of the Royal Society and those of the Russian Imperial Academy of Sciences have been swung at five stations.

(3.) The principal triangulation has been executed as usual with the largest theodolites, the azimuthal circles of which have diameters of either 36 inches, or of 24 inches. The average theoretical probable error of the angles, and the average geometrical error, of the triangles—the amount by which the sum of the three observed angles of each triangle differs from 180° + the spheroidal excess—are shown in the table given in the margin. In the course of the operations of the present season two great circuits of triangulation have been closed, one formed by the chains of triangles on the meridians of 80° and 82° and the parallels of 18° and 24°, the other by the chains on the meridians of 75° and 78° and the parallels of 13° and 18°. A series of triangles has been commenced on the meridian of 72½°, emanating from the Karáchi (Kurrachee) Longitudinal series and trending northwards, which, with another series to be executed on the meridian of 70°, will suffice to fill the gap which at present exists in the triangulation of Western India. The Brahmaputra Series, meridian 90°, has been so far advanced northwards that in all probability it will be completed during the next field season.

Series.	Probable Errors of Observed Angles.		Geometrical Errors of Triangles.		Nature of country operated in.
	Number.	Amount.	Number.	Amount.	
I.	63	±0″·16	21	0″·45	Hills.
II.	48	·21	16	·36	„
IV.	42	·15	14	·33	„
V.	75	·14	25	·65	„
VI.	48	·29	16	·94	Plains.
Averages,...	...	±0″·18	...	0·56	

(4.) The secondary triangulation which is being carried up the Assam Valley has made very little progress, the reasons of which will be found explained in Section III.

(5.) The transit instruments, chronographs, astronomical clocks and other apparatus for this Survey—the construction of which was commenced ten years ago in England and France, under Colonel Strange's superintendence, and has been reported on by him from time to time in various communications to the Royal Society and the Royal Astronomical Society—were received in this country in time to permit of their being used in the present year. They were employed in the determination of the differences of longitude between Madras, Bangalore and Mangalore by the electro-telegraphic method. The astronomical determinations of latitude were suspended to allow of the Officers usually engaged thereon being employed on the longitude operations.

(6.) The pendulum observations which were commenced in the year 1865 by Captain Basevi, and suspended on the death of that Officer in 1871, have been resumed; the operations remaining to be done in India have been completed; the

pendulums have been taken back to England, and final observations are now being made at Kew, the base station.

(7.) Much attention has been paid to the requisite measures for the protection of the stations of this survey, which are scattered over all India; it has been found that a large proportion of those which were constructed even at the commencement of the present century are still forthcoming, though no steps appear to have been specially taken to ensure the protection of any of the stations until the years 1865-66, when stringent orders on the subject were issued by the Government of India, lists were circulated to the District Officials, and periodical reports on the condition of each station were called for.

(8.) The final reduction of portions of the triangulation and the publication of the Volumes of the "*Account of the Operations &c.,*" which give the results of this laborious operation, have made satisfactory progress; the publication of charts shewing the preliminary results, which are deduced on the completion of each field season's operations, has been kept up to date, as has also that of the maps which are constructed by the three Topographical Parties. A second edition of the map of Turkestan, which contains much new information of the geography of Central Asia, has been published, as also various other maps which will be duly described hereafter.

(9.) During the summer of 1872 I was employed in the India Office, London, in examining the condition of the copper plates of the Indian Atlas, and in carrying out the requisite measures for the completion of such portions of the Atlas as it was considered desirable to have engraved in England rather than in India. These operations have been fully reported on in Mr. Markham's Abstracts of the Reports of the Indian surveys, published in 1872 and 1873. I need here only add that a portion of my duties in England was to acquire sufficient information of the practical details of superposing a surface of steel on an engraved copper plate, by the electro-type process, to be able to introduce the method into this country, for employment in the Surveyor General's Office in Calcutta. The requisite apparatus was duly provided in England, and on its arrival in India I proceeded from my Head Quarters in Dehra Doon to Calcutta, in order to initiate the process, which was soon placed on a satisfactory footing, and is now worked whenever necessary.

(10.) While in England my attention was drawn to the tidal investigations which were being carried on under the direction of a Committee of the British Association presided over by Sir William Thomson; I found that it was very desirable that the tidal operations in this country should, when resumed, be conducted in a similar manner, in order to contribute towards the attainment of a better knowledge of the laws of the tides. With the sanction of the Secretary of State for India I made arrangements to procure all the requisite self-registering instruments, and to acquire the practical details of the reduction of the observations by the method of harmonic analysis which is practised and recommended by the British Association. The instruments have been received in this country, thoroughly examined, and put into good working order; and all the requisite arrangements have been made for commencing operations by a series of tidal determinations on the coasts of the Gulf of Kutch, which will be immediately undertaken.

(11.) I landed at Bombay on the 31st October 1872, after an absence of nearly two years from India, and on the following day I resumed the direction of the Great Trigonometrical Survey, which had been administered during the whole term of my absence by Major T. G. Montgomerie, R.E., to whom my best thanks are due for the manner in which he conducted the duties of the Department, and whose services have already been acknowledged by the Government of India and the Secretary of State.

(12.) I now proceed as usual to report on and give an abstract of the operations of the several Survey Parties and Offices. Further details will be found in the Extracts from the Narrative Reports of the Executive Officers given in the appendix, which also contains a paper of "Notes on the maps of Central Asia and Turkestan" which have been published in this Office under my superintendence.

NO. I.—TRIGONOMETRICAL.

THE BILÁSPUR SERIES, SOUTHERN SECTION, MERIDIAN 82°.

(13.) The longitudinal chain of triangles which extends from Bombay to Bider and thence to Vizagapatam was completed during the field season of 1871-72. I then determined to utilize the opportunity afforded by the presence of Mr. Rossenrode and his party in the neighbourhood, to carry a triangulation on the meridian of 82°, from the said longitudinal series northwards, to meet the triangulation on the same meridian which was being brought down from the Calcutta Longitudinal Series by Mr. Keelan, and which could be more easily and satisfactorily executed by surveyors already familiar with and located in the country, than if it were conducted continuously from north to south by other surveyors new to the ground.

(14.) Mr. Rossenrode had much difficulty in recruiting his establishment, in providing pack-bullocks—the only means of carriage available in a country which is very hilly and intricate and is almost wholly devoid of roads—and in obtaining carriers for his great theodolite; a panic had seized the indigenous hamils or bearers in consequence of the mortality which had prevailed among them during the operations of the preceding field season, and men had to be imported from Hazaribagh who had been previously employed by Mr. Rossenrode. All the preliminary arrangements were however completed in time to permit of the party taking the field in the middle of November, the earliest date at which it is judicious to do so in this region of malaria and fevers. After a month's march from Vizagapatam Mr. Rossenrode reached the terminal stations of last season's triangulation where his work had to commence, and in the three following months he carried the final operations northwards, a distance of 96 miles, to the parallel of 20° 24′, where they formed a junction with Mr. Keelan's operations on the northern section. Principal observations were taken at 17 stations, forming three polygonal figures which cover an area of 2,360 square miles. An azimuth of verification was also determined by astronomical observations.

PERSONNEL.

W. C. Rossenrode Esq., Depy. Supdt. 3rd Grade.
Mr. H. Beverley, Surveyor 1st Grade.
„ F. Bell, Surveyor 3rd Grade.
„ E. P. Wrixon, Asst. Surveyor 3rd Grade.

(15.) During the previous field season Mr. Rossenrode had been unable to have a sufficient number of secondary points fixed to render his operations as valuable as they should be for geographical purposes; he had only two assistants and was obliged to employ them chiefly in the preliminary operations for the great triangulation. During the present season this omission has been amply rectified, and a large amount of secondary triangulation has been executed, over an area of upwards of 5,000 square miles, in which there are 83 stations whose position and height have been determined, and 203 points fixed by intersection but not visited.

(16.) Mr. Rossenrode and his assistants are to be much congratulated on the satisfactory completion of these arduous operations. The country in which they were laboring is one of the most malarious and deadly in all India. It was in this region that Colonel Everest commenced his career as a Trigonometrical Surveyor, in the year 1818: a few months afterwards he was stricken down by jungle fever, the most baneful enemy of the operations of the survey. Half a century was allowed to elapse before the work was resumed; but in 1869-70 Mr. George Shelverton was deputed to take it up; he too suffered much from fever, but he remained at his post, with a steady persistance and self devotion which, in the following year, cost him his life, and lost the Government the services of an able and very deserving officer. In this last season of the operations, Mr. Rossenrode and each of his European assistants and the whole of the native subordinates and camp followers, without a single exception, suffered more or less from fever, but fortunately of a less virulent type than had been met with to the south, and the number of fatal cases was comparatively slight.

(17.) In his Narrative Report, Mr. Rossenrode gives an interesting description of the Banjáras, the class of people by whom the chief trade of the country is conducted, and whose existence appears to be devoted to purchasing grain in the valleys and plains in the interior and carrying it to the towns on the sea-coast for sale; the roads, or rather foot paths, being of the very worst description, passing over rugged hills and through tangled forests, the grain has to be transported on pack-bullocks; and the Banjára and his wife and family and all his belongings, travel with the bullocks, and have no other home than their tents and camping grounds.

(18.) In the ensuing field season Mr. Rossenrode and his party will be employed in Burma, in resuming the operations which were suspended in the year 1870.

NO. II.—TRIGONOMETRICAL.

THE BILÁSPUR SERIES, NORTHERN SECTION, MERIDIAN 82.°

PERSONNEL.

H. Keelan Esqr., Depy. Supdt. 3rd Grade.
Mr. L. H. Clarke, Surveyor 3rd Grade.
„ J. C. Clancey, Asst. Surveyor 4th Grade.

(19.) The principal triangulation which was required to form a junction between the terminal points of the operations of the previous year in this section of the series and those of the present year in the southern section, has been completed by Mr. Keelan, by observations at ten stations forming four quadrilateral figures which extend over a direct distance of 55 miles and cover an area of 680 square miles. A verificatory azimuth has also been determined by astronomical observations at one of the principal stations. This portion of the work has been well done, but in other respects the performances of the field season are not as satisfactory; no secondary triangulation was executed, nor were any attempts made to connect the stations of the Topographical and Revenue Surveys, of which there are several in the neighborhood of the Trigonometrical Stations; this work will have to be done before the operations can be considered to be complete. Mr. Keelan describes the country as the wildest tract it has ever been his lot to work in, covered with forest and presenting no well defined points to fix; his party had been materially weakened by the transfer of one of his assistants to other duties; but as the amount of the principal work which had to be performed was not very much, I am of opinion that with better arrangements and a little more enterprise the secondary work as well as the primary would have been completed.

(20.) By the junction of the two sections of this chain of triangles, the circuit formed by the Jabalpur and the Bilaspur Meridional Series and by the Calcutta and the Bider Longitudinal Series, has been closed; its length is about 1,130 miles, and the discrepancies at the side of junction—as exhibited on the completion of the preliminary calculations of the triangulation, without any correction for errors generated in the course of the circuit—are as follows; linear, 0·49 of a foot in 14·94 miles, which is equivalent to the six millionth part of the side of junction; in latitude 0″·28, in longitude 0″·02, and in height 20 feet.

NO. III.—TRIGONOMETRICAL.

THE OPERATIONS IN THE ASSAM VALLEY.

(21.) The extension of the triangulation into the upper portion of the Assam Valley has long been a desideratum, in order to connect the Revenue Sur-

veys of the Sibságar and Lakhimpur districts—which were commenced several years ago—with the general survey, and also to fix points on the hill ranges lying to the north of the valley, for the elucidation of the geography of regions which are at present inaccessible to Europeans, being occupied by various independent hill tribes. Every effort has been made to push on this triangulation as rapidly as possible, but the difficulties met with have been very great, and the progress has been far slower than that of any similar operations of this Survey in modern times.

(22.) The difficulties arise from the following causes. *First*, the whole surface of the country, in the hills as well as the plains, is covered with patches of forest and with dense jungles of bamboo and long grass; in every instance more or less clearance is required to render the stations mutually visible; when the stations can be placed on hill peaks it is only necessary to cut the trees down to the level of the summit; but in plains the entire length of line between contiguous stations has to be cleared, and some idea of the labor may be formed from the fact that a single line occupied a party of twenty five cutters thirty six days to clear; if a rainy season intervenes between the cutting of a line and the final observations, a second clearance becomes necessary, as in these regions grass and bamboo jungle grows up very rapidly on the line during the rains. *Secondly*, the country is very sparsely inhabited; supplies and laborers have frequently to be imported from a distance, and even where large villages are met with the inhabitants can only with great difficulty be induced to render any assistance, though highly paid for it. *Thirdly*, the most healthy time of the year for field work is usually the least favorable for observations of distant points; the atmosphere is always clearest and most transparent immediately after the termination of the rainy season, and in the brief period which usually occurs between the first showers—the *chota barsát*—and the setting in of the regular rains; but at these times malaria and jungle fever are most rife and the country is very deadly, more particularly for persons employed in field operations which necessarily entail great exposure. When the dry season sets in the villagers invariably burn down the grass and bamboo jungle, and then the atmosphere becomes pervaded with smoke, which hangs like a pall over the whole country, and shuts out from view all distant objects and sometimes even near ones; at these times observations become impossible, and the surveyors have to be employed in the preliminary operations of selecting and constructing stations and clearing lines.

(23.) The Assam Series was commenced in the season of 1867-68 at the stations of the principal triangulation in the neighborhood of Gowhatty, by Lieut. Larminie, R. E., who was only able to carry it over a distance of 56 miles in that and the following field season. In his anxiety to push on the work more rapidly Lieut. Larminie took the field, at the commencement of the season of 1869-70, so soon after the cessation of the rains that most of his men were stricken down with fever, and by the time they had recovered and were fit for work the favorable season for observations had passed, and the party had to be employed in preliminary operations for future work. In 1870-71, the triangulation was advanced a direct distance of 86 miles by Mr. W. C. Rossenrode, the best season's work yet performed in the course of these operations, but due in some measure to the preliminary operations which had been previously completed by Lieut. Larminie. In the following year Mr. W. G. Beverley carried it 40 miles further.

(24.) During the field season now under review several points have been fixed on the hill ranges to the north of the valley, but the principal chain of triangles has been advanced a distance of less than twenty miles. This is mainly due to the circumstance that political considerations necessitated the abondonment of the original design of carrying the operations over the northern spurs of the Nága Hills, for which arrangements had been made; Mr. Beverley was therefore compelled to turn down into the plains of the Brahmaputra River, the region of tree-forests and dense grass and bamboo jungles, where

PERSONNEL.

W. G. Beverley Esqr.	Asst. Supt. 2nd	Grade.
Mr. G. A. Harris	Asst. Surveyor 1st	„
„ W. G. O'Sullivan	„ „ 1st	„
„ J. O. Hughes	„ „ 4th	„

every line has to be opened by laborious clearances. I am sorry to have to add that much delay was also caused by an injudicious selection of the two stations at which the season's operations terminated; the indispensable precaution of carrying a trial line between these points before constructing the towers had been neglected, and when the final line came to be cleared a large house was found standing midway between the two stations; this house was too valuable to be pulled down and therefore the towers had to be built up to a considerable height and then high platforms had to be temporarily erected on them for the support of the lamps and heliotropes. All this caused much delay, which was the more to be regretted as it happened at a time when the atmosphere was favorable for observations, before the natives had commenced their periodic burnings of the grass jungles.

(25.) The final operations have now been carried up to points in the vicinity of the Dhansíri River, one of the stations being situated at Gola-ghat. Preliminary operations for next field season have been carried up to within seven miles of the town of Síbságar. Several high mounds and ruined temples have been met with, on the left bank of the Brahmaputra river, which are likely to be made to serve as sites for stations; but this will depend on whether corresponding sites can be met with on the long island of Majhili, which stretches from a point a little below Síbságar to a point near the junction of the Dhansíri river with the Brahmaputra. On that island it will be necessary to have five or six stations, only two of which have as yet been selected. Mr. Beverley reports "that Mr. O'Sullivan, who was employed in this duty, would probably have completed the selection had not his progress being stopped from want of provisions," and that it will be necessary next season to carry supplies for men and animals in boats from below, and to make such other arrangements as may render the surveyors wholly independent of local assistance. He also states that this is the most difficult portion of the triangulation which remains to be executed, and that when the Majhili island has been left behind the operations may be readily advanced into any portion of the Upper Assam basin.

(26.) Mr. Beverley reports that the secondary triangulation has completely defined the Dufla Hills, which form the lower range on the northern side of the valley, between the meridians of 93° and 94°; the points laid down will be useful in the projected survey operations to define the British Boundary. Some peaks have been observed in the snowy ranges beyond, but as they were only seen on two occasions, they cannot yet be considered to be definitely fixed. There is still a considerable blank in the determinations of hill peaks west of 93°, which Mr. Beverley hopes to be able to fill in at the commencement of next field season, should the atmosphere be sufficiently clear to permit of his seeing the hill ranges.

NO. IV.—TRIGONOMETRICAL.

THE JODHPUR SERIES; MERIDIAN 72½°.

(27.) Ground was broken on this series for the first time during the field season under review. In the previous season Lieutenant Rogers had been employed in completing the revision of the section of the Great Arc between the base-lines at Bangalore and at Bider, after which he returned to Bangalore to spend the recess season. He had therefore in the first instance to proceed with the greater portion of his party and instruments by rail from the centre of the Madras Presidency, to Ahmedabad, the northernmost station of the Bombay and Baroda Railway, and then to march *viâ* Deesa to Erinpúra, where he had arranged to meet the agent of the native state of Jodhpúr who had been deputed to attend him throughout his operations.

(28.) The Jodhpúr Series is one of the two internal chains of triangles which remain to complete the great figure known, departmentally, as the North-West Quadrilateral, the exterior chains of which directly connect the base-lines at Sironj (in Central India), Dehra Doon, Chach (near Attock) and Karáchi. Operations were commenced at the stations of Súnda and Bonik of the Longitudinal Series which forms the southern flank of the Quadrilateral, and they were carried northwards with a view to closing eventually on the Sutlej Series.

PERSONNEL.

Lieut. M. W. Rogers, R.E., Asst. Supdt. 1st Grade.
Mr. W. C. Price, Assistant Surveyor 1st „
„ C. P. Torrens „ „ 3rd „
„ A. Bryson, „ „ 4th „
„ W. Oldham, „ „ 4th „

(29.) As no opportunity had been previously afforded of undertaking the usual preliminary operations for final triangulation, Lieutenant Rogers occupied himself for some weeks in selecting sites for stations and having the necessary structures erected thereat. When this work had been sufficiently advanced to be entrusted to his assistants, he commenced the measurement of the principal angles, and fixed twelve new stations, forming two polygonal figures and a quadrilateral which extend over a direct distance of 95 miles and embrace an area of 3,706 square miles. The preliminary operations were advanced to a distance of 52 miles beyond, in readiness for next field season.

(30.) The country passed over is very favorable for our operations; it is sandy and free from the dense growth of forests and tropical vegetation which elsewhere has caused such difficulties and retarded progress; and it has numerous isolated hills and sand-hillocks which present favorable sites for stations of observation. The chief difficulty met with was in the scanty supply of water, and the bad quality of the little water that was to be had, and this difficulty will increase as the operations advance farther into the deserts of Rájputána. On the other hand the Jodhpúr Durbar—unfettered by restrictions such as are placed on the British Officials in Assam—rendered most cordial and effective assistance, and Lieutenant Rogers reports that he has never before met with so little hindrance and annoyance in the prosecution of his operations.

(31.) In addition to the principal operations, a goodly amount of secondary work was done, fixing the positions and heights of 15 visited stations and 50 unvisited stations, in an area of 2,443 square miles, mostly in the Nizam's Dominions where the operations had been arrested at the end of the preceding season by the ill health of the assistant employed on them. Two groups each of four subsidiary stations, on the Great Arc, in latitudes 19° 5′ and 20° 44′, where Captain Herschel had taken astronomical observations for latitude, were connected with the principal triangulation.

(32.) The general progress of the operations and out-turn of work is very creditable to Lieutenant Rogers and his assistants.

NO. V.—TRIGONOMETRICAL.

THE OPERATIONS ON THE MERIDIAN, 75°, AND THE PARALLEL, 13°, OF MANGALORE.

(33.) The triangulation on the meridian of Mangalore is primarily dependent on the Bombay Longitudinal Series from which it was carried southwards, in the field seasons 1865-67, by Captain Haig and Lieutenant Trotter, to the parallel of 14½°, where the operations were suspended. During the present field season it has been resumed and completed by extension southwards until it formed a junction with the Longitudinal Series which connects Mangalore with Madras.

(34.) The recent operations have been performed by Major Branfill and Lieutenant McCullagh, who also completed a few triangles on the Longitudinal Series the measurement of which had been arrested by a variety of untoward circumstances during the preceding field season. When the survey party commenced operations this year, so large an amount of work had to be performed to forge the remaining links which were required to connect and complete the two chains of triangles, that the chances against its being done in one season were very considerable. The work was almost too much to be finished in the given time, but on the other hand it was too little to occupy two field seasons profitably. Such instances are not of unfrequent occurrence in the operations of this Department, and they occasion much anxiety; for when triangulation is completed in one part of the country it may—and very generally does—happen that the nearest point at which the surveyors can be profitably employed is several hundred miles distant, and thus a great portion of the naturally limited and too short field season is liable to be devoted to the unremunerative occupation of marching from one place to another.

PERSONNEL.

Major B. R. Branfill, Depy. Supdt.			2nd Grade.
Lieut. McCullagh, R.E., Asst.	„	1st	„
Mr. J. W. Mitchell, Asst. Surveyor		1st	„
„ O. V. Norris,	„	3rd	„
„ C. D. Potter,	„	3rd	„
„ E. W. Laseron,	„	3rd	„

(35.) In the present instance there was not only a large amount of work to be done, but the most of it lay on the crests of the Western Ghats in a region as to which Lieutenant Trotter had reported—at the close of his operations in 1867—that "the progress of the future operations will now be necessarily slow, the physical features of the country and the bad climate being both difficult to overcome; the country over which the principal triangulation will pass is very hilly, wild and thinly populated, and carriage is only to be procured with great difficulty."

(36.) The design of the triangulation had been laid out some years previously, but there was reason to fear that this important work had not been done with sufficient circumspection and care, for two instances had already been met with in which certain of the stations selected were found to be mutually invisible, whereby great delay was occasioned, for the observations had to be suspended until new stations had been selected and constructed; thus this essential portion of the operations required to be carefully examined, which added in no small measure to the labors of the field season.

(37.) Warned by past experience of the delays to which operations in Southern India are liable when commenced early in the season, before the cessation of the autumnal rains of the north-east monsoon, Major Branfill deputed Lieutenant McCullagh to the northernmost portion of the triangulation, to commence observations in the district in which the influence of the monsoon is least felt; thus favorable weather was secured and the observations of the principal angles were carried on continuously without any hindrance. Meanwhile Major Branfill proceeded in person to examine the stations already selected, and finding that the original plan, if adhered to, would entail the crossing and recrossing of the ghats such a number of times as to cause great delay, and render it impossible to complete the operations in the desired time, he re-modelled it in such a manner as to remedy this defect as far as practicable, and thus contributed in no small measure to the success of the season's operations.

(38.) The out-turn of work is as follows; 59 angles were measured at 19 principal stations forming two polygonal and two quadrilateral figures, which extend over a direct meridional distance of 105 miles, embrace an area of 3,330 square miles and complete the connection between the Mangalore meridional and longitudinal series; the positions and heights of 74 secondary stations, and the positions of 53 unvisited points, have been fixed. These results are the more satisfactory in that much of the marching about had to be done on foot, the roads—or rather foot-paths—being in many instances impracticable for horses.

(39.) Three of the principal stations newly laid down are those at which astronomical observations for latitude had been taken last year by Captain Campbell, and one of these—in the neighbourhood of Mangalore—is the western extremity of the Madras arc of parallel, the measurement of which has been

undertaken during the present season and which will be described in section X of this report. An azimuth of verification was measured by Lieutenant McCullagh at one of Captain Campbell's stations to the north, and another at the same time by Major Branfill at Mangalore, a second great theodolite having been sent round by steamer from the Mathematical Instrument Department at Calcutta for the purpose, which was returned on the conclusion of the observations.

(40.) On the return of the party to recess quarters the reduction of the principal observations was taken in hand, and it was found that the geodetic elements of the triangles from the Bider base-line and the Bombay longitudinal series agree very closely with those of the triangles from the Bangalore base, and the Mangalore longitudinal series; the length of the circuit formed by the triangulation is about 1,050 miles, and the discrepancies at the side of junction are as follows; linear, 0·06 inches per mile—or almost exactly the millionth part of the side—in latitude 0″·07, in longitude 0″·19, in azimuth 3″·09, and in height 5 feet. These results are at present provisional only, but it is improbable that they will be materially altered, and they may be accepted as a satisfactory evidence of the accuracy of the operations, when the length of the circuit of triangulation thus completed and closed is taken into consideration.

NO. VI.—TRIGONOMETRICAL.

THE BRAHMAPUTRA SERIES, MERIDIAN 90°.

(41.) The operations on this series, during the two previous field seasons 1870-72, had been entirely restricted to the preliminary work of selecting sites for stations, erecting towers on them, and clearing the intermediate lines; thus the field season now under review was mostly devoted to the measurement of the principal angles and to secondary work.

(42.) Captain Carter took the field at an early date, with an establishment composed for the most part of the surveyors who had worked with him on the spirit-leveling operations of the previous year, as the surveyors hitherto employed on the Brahmaputra Series had been transferred to the triangulation in Assam. He and all his assistants were new to the ground, but nevertheless satisfactory progress was made.

PERSONNEL.

Captain Carter, R.E., Deputy Supdt. 2nd Grade.
Mr. A. W. Donnelly, Surveyor 2nd Grade.
„ C. J. Neuville,* „ „
„ H. Healy, Assistant Surveyor 4th Grade.
Narsing Dass, Sub-surveyor.
Amjad Alli, do.

* Mr. Neuville was on leave of absence on medical certificate during the entire field season.

(43.) At the outset considerable delay was occasioned in consequence of one of the towers at the side of extension previously completed having been washed away by the river. A new station had therefore to be built and connected with those behind before any further advance could be made. 16 principal triangles—forming two polygonal figures and the greater part of a third—were completed; they embrace an area of 865 square miles, wholly in the plains, and extend over a direct distance of 56 miles.

(44.) This was Captain Carter's first season's performance in principal triangulation, his work in this Survey having hitherto been mostly topographical—in Kashmir and Ladak, and in Kumaon and Garhwal—and geographical, as when he served with the Abyssinian expedition and on the Peshawar frontier. He was much let and hindered by unfavorable atmospheric conditions throughout almost the entire field season; during the mornings for several hours after sunrise the country in which he was working was covered with a dense fog of mists and exhalations; in the evenings this was succeeded by the smoke of the village fires which were generally impenetrable to the lights of the signal lamps; thus observations during the night, which is usually the most favorable time of all for them, were rarely practicable, and as a rule they could only be taken during a few hours

before sun-set to heliotropes; towards the end of March even the light reflected from heliotropes could not penetrate the dense smoke then caused by the burning of the grass and rice-stubble which is always done at that time of the year. The only chance then remaining of being able to prosecute the observations was in getting a fall of rain to clear the atmosphere; but this year little rain fell up to the end of April, by which time the whole party was more or less prostrated by fever and over-exertion. Thus Captain Carter was reluctantly obliged to close work before he had completed his last polygon, but he succeeded in carrying the operations up to a point sufficiently near the terminus of the series to render it highly probable that the triangulation will be completed during the ensuing field season.

(45.) A series of secondary triangles was carried eastwards from the principal series to fix the town of Mymensingh.

No. VII—TOPOGRAPHICAL.

THE SURVEY OF KATTYWAR.

(46.) The operations of this survey have made very good progress, an area of 2,642 square miles having been topographically surveyed, and an area of 2,680 square miles triangulated in advance for the work of next year. This large out-turn is due in some measure to the circumstance that the topographical operations lay chiefly in the northern portions of Jhalawar, in a bare and sterile country which is bordered on the north by the Runn of Kutch, and presents few features for survey as compared with the rich districts to the south. 740 miles of Taluka boundary lines have been traversed with the theodolite and chain, as well as 409 miles of lines to check the detail work of the plane-tablers.

PERSONNEL.

Captain H. Trotter, R.E., Dy. Supdt. 3rd Grade, in charge up to 6th April 1873, when relieved by Capt. A. Pullan, S.C., Offg., Dy. Supdt. 3rd Grade.
J. McGill Esqr., Assistant Superintendent.
Mr. F. Ryall, Surveyor 4th Grade.
" J. Wood, ditto 4th "
" N. C. Gwynne, Assistant Surveyor 1st Grade.
" T. Rendell, ditto 1st "
" E. Wyatt, ditto 2nd "
" W. Fielding, ditto 3rd "

Native Surveyors.

Visaji Ragonath, Govindji Mahala, Narsu Dinkar and seven others.

(47.) The topography of the eastern half of the province has now been nearly completed, the operations having been advanced westwards to within a short distance of Rajkote, the chief town in the province. Of this town a survey will be made, on the scale of 12 inches to the mile, during the ensuing field season. When the operations of the general survey reach the shores of the Gulf of Cutch, every effort will be made to connect them with the survey of that Gulf which was made by Lieutenant Taylor, I. N.; the original maps of the survey have been lost, but Lieutenant Taylor had fortunately retained copies for his own use, and lithographs of these have been made in England and sent out to this country.

(48.) Shortly before the termination of the field season Captain Trotter was withdrawn from the charge of the operations, and his services were placed at the disposal of the Foreign Department, with a view to his joining the mission which is about to be sent by the Government of India to the Atalik Ghazi, the present Ruler of Eastern Turkestan.

(49.) The boundary traverse lines have all been reduced and found to stand the usual tests in a satisfactory manner; there are fourteen circuits whose united lengths amount to 149 miles, and which close with an average error of 0·49 per 1,000, and there are forty-five traverses between trigonometrical stations, the united lengths of which amount to 590 miles, and whose average difference from the corresponding trigonometrical values is 1·04 per 1,000; the greater discrepancy in the second instance is clearly due to a slight, but practically unimportant error in the unit of length of the measuring chains as compared with that of the triangulation.

(50.) The operations of the year have been reported on by Captain Pullan; but Captain Trotter has furnished some interesting memoranda—which will be found at page 27–a of the appendix—descriptive of the aspect of the country surveyed and of the adjoining portion of the Runn of Cutch; also of the salt works recently established by the British Government in the neighbourhood of the Runn, at Patri, which place has been connected with the Bombay and Baroda line of railway, by a branch line from the station of Viramgám.

NO. VIII—TOPOGRAPHICAL.

THE SURVEY OF GUZERAT.

(51.) The operations of this survey, during the present year, embrace the topography of portions of the Kaira collectorate, the whole of the Pitlád Mahal of the territory of the Gaikwar of Baroda, and nearly the whole of the Cambay territory. The area finally completed was 1,175 square miles, in addition to which an area of 791 square miles was triangulated, and 773 linear miles of traverses were executed in advance for future topographical operations.

PERSONNEL.

Major C. T. Haig, R.E., Offg. Dy. Supdt.		1st	Grade.
Captain A. Pullan, S.C., Asst.	Do.	1st	„
Mr. A. D'Souza,	Surveyor	2nd	„
„ A. Christie, Asst.	Surveyor	1st	„
„ C. H. McAFee,	ditto	1st	„
„ E. J. Connor,	ditto	2nd	„
„ J. Hickie,	ditto	3rd	„
„ G. D. Casson,	ditto	3rd	„
„ G. T. Hall,	ditto	4th	„

Sub-Surveyors.

Gopal Vishnu and eight others.

Revenue Surveyors.

Mr. A. Dalzell, Asst. Supdt. and 4 Native Surveyors.

(52.) When this survey of Guzerat was commenced I had reason to hope that much of the work of the elaborate Revenue Surveys of the British portions of the Province might be combined with it, so as to permit of the construction of a good topographical map on a scale considerably larger than that of the standard scale—one inch to the mile= $\frac{1}{63360}$—of the Indian Topographical Surveys. Captain Nasmyth, who had been deputed to examine the revenue maps, had reported "that "they contained a variety of details which will suffice for ordinary engineering "requirements in the laying out of railways, tramroads and canals for irrigation, "such as the growing necessities of this fruitful province are evermore urgently "demanding." Subsequently however, when the practical test of going over the ground and determining the true distances between the boundary pillars of the villages and other obligatory points was applied, by the operations of this survey, large discrepancies were met with in so many instances as to create an impression—on the part of the Executive Officers—that the revenue maps were not to be relied on for topographical purposes, and that any attempt to utilize them would be more laborious, in the long run, than to make a new survey of the entire province.

(53.) But in India topographical surveys are invariably executed by the method of plane-tabling on a basis of points fixed by triangulation or traverses, and not by the ordinary land-surveyor's method of chain measurements. For surveys on small scales, plane-tabling suffices admirably, and it is unquestionably the best method that could have been devised for the preliminary or first survey of India; it is particularly well suited for the delineation of unwooded hill tracts and broken ground; it is moreover admirably adapted for surveys of Native States which do not need to be very elaborately executed, for it may be carried on without any chain-measurements, operations which are liable to cause considerable suspicion and alarm in the native mind. But I am of opinion that it is very ill adapted for the survey of such a country as Guzerat, which is a rich and fertile plain covered with trees and habitations, and with numerous high enclosures which cut off the view in all directions, and embarrass operations which can only be carried on satisfactorily when the surveyor is able to see three or four of

his surrounding fixed points. Moreover the process of plane-tabling is not susceptible of being independently checked and verified in as satisfactory a manner as that of chain measurement, and consequently much has to be trusted to the skill and integrity of the surveyor. Another objection—and one of the gravest of all—is that there is no numerical record of the angular and linear determinations, such as would facilitate references to clear up disputed points as to boundaries and other matters, or to permit of the work being mapped on a larger scale whenever it may be desirable to do so; thus before an enlarged map could be constructed it would be necessary to make a new survey of all the details of the ground, and only the triangulation and traverses on which the first survey was based would be available for the second.

(54.) For these reasons, and because geographical maps of Guzerat are already available, which—though much inferior to the preliminary maps of the Survey Department—have for many years been made to suffice for general purposes, it is obvious that the present topographical survey of Guzerat should be so conducted as to furnish maps of greater general utility than the standard preliminary maps of the Department. This can only be accomplished by supplementing the triangulation and the traverses on which the subsequent work is based by a considerable amount of accurate chain measurement of the details of the ground, and then commencing the plane-tabling, which would thus become rather an examination of the previous work and the means of giving the finishing touches, than what it now is—the sole means of acquiring all the details.

(55.) But the present organization of Topographical Survey Parties is not well adapted for operations which involve the laborious and slow process of chain measuring; it consists of a highly paid staff of surveyors—mostly Europeans—who are skilled in the use of the theodolite and the plane-table, and many of whom possess considerable artistic skill in the delineation of the features of the ground, an operation for which European agency is always desirable, as natives of this country are rarely met with who can do it well. Moreover it is not desirable to employ natives in positions in which they must be trusted and yet cannot be very closely supervised without going through examinations which are almost as laborious as the original operations. Consequently as a rule there are very few native surveyors in the establishment of a topographical party. But chain measuring is a process which natives can be readily taught to execute with all the requisite accuracy and which can be made self-verificatory, and on which it is therefore not desirable to employ a highly paid staff of Europeans. Consequently a large increase in the proportion of the native to the European element would have to be made before a topographical party would be in a position to undertake operations which involve considerable additional labor, without causing a material increase in the cost of the Survey, as measured by the relation between the actual outlay and the area surveyed.

(56.) But as all changes of organization take some time to carry out, it will be evident that the only prospect of obtaining a more detailed and elaborate survey of Guzerat than the standard preliminary survey of other parts of India, by means of the agency which was available for the purpose, lay in combining with the topographical operations the results of the extensive measurements of minute details which had already been executed by the revenue surveyors. It is true that those measurements had not been performed with any pretensions to a high order of accuracy; the idea of conducting them in such a manner as to serve the purpose of a general survey had been discussed at the outset and deliberately set aside, on the grounds that the doing so would imperil the success of the financial operations, which were deemed of greatest importance. Thus it had come to pass that each village had been surveyed and mapped separately, without any attempt to make a systematic connection of the several surveys, which were consequently isolated. Nevertheless a considerable amount of minute detail had been measured, and in many places with considerable care; the principal marks to which the measures had been referred were still in existence, and their positions could be fixed by the operations of the topographical surveyors; and thus a com-

bination could be effected which might reasonably be expected to give a much larger amount of minute detail, and more accurate results, than mere plane-tabling over ground which is pre-eminently unsuited for such a system of survey.

(57.) The first attempts which were made to incorporate the revenue survey details failed, apparently for two seasons; *first*, the original marks which were fixed by the topographical surveyors were so few that the intermediate details had to be fitted in by combining several of the village maps together, and it was found that this could not be done satisfactorily; and *secondly*, the marks which were selected to be fixed were almost invariably situated on the exterior boundaries of the village lands and rarely in the interior, whereas—for reasons which will now be explained—the interior marks would have been best adapted for the purpose. In the Bombay Revenue Surveys a system of operation has been followed which is diametrically opposite to that of the corresponding surveys in Bengal; one or more so-called 'base lines' are always measured in the interior of the village lands, in the first instance, and all subsequent measures are referred to these lines by off-sets; whereas in Bengal the periphery of the village is first surveyed, and all the interior details are subsequently referred to it. The Bombay system necessarily gives greatest accuracy in the central portions and least on the exterior boundary lines of the villages, while the converse is the case with the Bengal system; the former is unsuited, *per se*, for effecting a combination of the village maps into a general map, whereas the latter is peculiarly well adapted for this purpose, and it is mainly owing to this circumstance that the revenue operations in Bengal have been so valuable for topographical purposes, while in Bombay every attempt to construct general maps from the revenue materials has hitherto failed altogether or met with very qualified success.

(58.) Immediately after my return to India I proceeded to Poona—where the Offices of the Guzerat and Kattywar Survey parties are established during the recess—with the object of inspecting the operations, and more particularly of ascertaining what had been or could be done towards utilizing the revenue survey materials. I found that little had been done hitherto, but that Major Haig was fully alive to the importance of the measure and much more sanguine as to its feasibility than any of his predecessors had been. I had consultations with Colonels Francis and Prescott, under whose superintendence the Revenue Surveys had been carried out, the details of which I wished to combine with the topographical operations. Eventually the conclusion was arrived at that in order to effect a satisfactory combination it would be necessary for Major Haig to be supplied with all the data of the revenue survey measurements, as given in the original field books, in addition to the lithographed village maps which had hitherto been the only materials available for the purpose. This however would necessitate a certain amount of co-operation on the part of the revenue surveyors with those of this survey, for the field books had been prepared in a manner which was intelligible only to persons familiar with the details of the operations and not to any one else; and they were written in the Guzerati language, not in English, the language in which all the records of this survey are kept; thus it was obviously desirable that a few of the revenue surveyors should be attached to the topographical survey, and placed at Major Haig's disposal, in order to enable him to reap the full benefits of the work which had been already done and to effect the requisite combination with his own work.

(59.) In the month of January a memorandum was drawn up, conjointly by Colonel Prescott and Major Haig, on the steps to be taken for detaching an officer and one of the native establishments of the Revenue Survey from their ordinary duties, and placing them at Major Haig's disposal. The said native establishments are usually comprised of surveyors only, and not of chain and flag-men or other underlings, for the services of such men are usually provided *gratis* by the villages in which the fiscal operations are being carried on. But in the operations of the professional survey these men are paid for by the Government, and their wages form a considerable portion of the cost of the survey. The sanctioned cost of a revenue native establishment is Rs. 500 per mensem, and

it was found that of this sum only two-fifths could be devoted to provide for surveyors and that three-fifths were required for the underlings. It was therefore proposed that a certain number of surveyors, whose aggregate salaries would not exceed Rs. 200 a month, should be drafted into the party to be formed to work under Major Haig, and that the sum of Rs. 300 should be made available for the wages of the underlings; also that Mr. A. Dalzell, Assistant Superintendent of the Revenue Survey, should be attached to the party. These proposals were speedily sanctioned by the Bombay Government.

(60.) It was not however until the 25th February, when the greater portion of the field season had passed, that Major Haig was joined by Mr. Dalzell and the native establishment, and was able to commence the long contemplated operations. Thus not very much work could be done, and it is still premature to draw any positive conclusions as to the result of the experiment. Major Haig reports that what has been done is sufficient to prove that great use may be made of the revenue survey materials in improving the accuracy of the topographical maps, when a more extensive and systematic connection is made between the fixed points of the two surveys than had previously been attempted; he also anticipates that the combination—when supplemented by the addition of the topographical details which have hitherto been purposely omitted from the revenue maps,—will permit of the construction of topographical maps of all the British portions of Guzerat on the scale of four inches to the mile, instead of the standard scale of one inch to the mile, and that this will be effected "with a proportional amount of additional detail and accuracy in minutiæ, for which improvement the public will be indebted to the Guzerat Revenue Survey." I sincerely trust that these anticipations will be realized, and I am very sure that Major Haig and his assistants will do their best to secure so desirable a result.

NO. IX.—TOPOGRAPHICAL.

HIMALAYAN SURVEYS IN KUMAON AND GURHWAL.

(61.) Considerable progress has been made in the Survey of the British Districts of Kumaon and Gurhwal, which has been for two years under the executive charge of Lieutenant J. Hill, R.E. Topographical operations were carried on in the Mána Valley, in the lake country to the east of Naini Tál, in the country round Lohúr Ghát, in the portions of the Gori and Rámganga valleys which lie in the vicinity of Askot, and in the part of the Sub-Himalayan tracts known as the Bhábar pergunnahs which is situated between Haldwáni and the Sardah River.

PERSONNEL.

Lieut. J. Hill, R.E., Offg. Dy. Supdt.		3rd	Grade.
„ H. J. Harman, R.E., Asst. Supdt.		2nd	Grade.
F. C. Ryall, Esq., *Asst.* Supdt.		2nd	„
Mr. J. Peyton, Surveyor,		2nd	„
„ J. Low,	„	3rd	„
„ L. Pocock, Assistant Surveyor,		1st	„
„ H. Todd,	„	2nd	„
„ T. Kinney,	„	3rd	„
„ E. F. Litchfield,	„	„	„
„ I. Pocock	„	4th	„

(62.) The district under survey has a range of over 25,000 feet in altitude, from the level of the lands at the southern foot of the Himalayas to that of the summits of the peaks of the great mountain chains in the interior; it consequently presents every variation of climate, from that of the lowlands of the Terai which are deadly during—and for several months after—the rainy season, to the regions of glaciers and perpetual snows which are only accessible during a few months of summer; this prevents the work being carried continuously over the entire district, and necessitates the employment of the surveyors in different localities at different times of the year, and thus entails the expenditure of a considerable portion of the field season in merely marching about; for the surveyors have frequently to be transferred considerable distances from ground where they can work

no longer, to other ground where they can be advantageously employed. It is further inconvenient in retarding the completion of the maps, and preventing the publication of the successive sheets in continuous order, as is generally done in other surveys.

(63.) During the year an area of 2,734 square miles has been topographically surveyed on the scale of one inch to the mile, and 353 square miles were triangulated in advance for future operations. This is a larger out-turn of work for the number of persons engaged than I am altogether prepared to welcome; for many difficulties and drawbacks were met with. In the higher ranges the winter set in unusually early and with exceptional severity, and elsewhere there was much fog and rain; the health of the surveyors was not good, three of them breaking down altogether; and labor was very scarce and difficult to procure, in the Bhábar more particularly, where cholera was rife among the inhabitants, who were leaving their homes panic-stricken. On the other hand a considerable portion of the area topographically surveyed is at an altitude ranging from 10,000 to 25,000 feet above the sea level, where the operations were necessarily restricted to sketching the principal features of the country without any attempt to obtain great accuracy or much minutiæ of detail, and the survey could be carried on with considerable rapidity. Lieutenant Hill examined a considerable portion of the work which has been done, and his report of the performances of the several surveyors is generally most satisfactory.

(64.) Lieutenant Hill has appended to his report an interesting table showing the average rate of work *per diem*, in square miles, in different portions of the district under survey. He finds that in the higher ranges, where the operations partake of the nature of a reconnoisance, from 9 to 14 square miles were surveyed daily; but that in the moderately high ground of the Sub-Himalayas the rate was about 3 square miles; in all the instances from which these calculations were made, the ground had been triangulated before hand and points fixed for the plane-table sketching of the topographical surveyors, whose rapidity of progress and accuracy of delineation is greatly dependent on the number of points previously laid down for them on the ground, and projected on their plane-table sheets, before they commence operations.

NO. X.—GEODETIC.

ELECTRO-TELEGRAPHIC DETERMINATIONS OF DIFFERENCES OF LONGITUDE, ON THE PARALLEL OF 18°.

(65.) All great national surveys have, for many years past, been made to contribute data for the determination of the figure of the earth; hitherto these data have mainly consisted of measurements of the distances between successive points situated on or near a common meridian, and of the astronomical arcs of amplitude between these points; it is only of late years that attempts have been made to obtain corresponding data from measurements of the distances between points situated on a common parallel of latitude, and of the astronomical arcs of amplitude between them. The reason of this is that the required astronomical data are very readily obtained in the case of meridional arcs, by determining the latitudes of the geodetic points, which is one of the simplest problems of practical astronomy; but on arcs of parallel longitudes are required instead of latitudes, and the astronomical determination of an absolute longitude—within the requisite limits of precision—is well nigh impracticable, and it could only be accomplished by observations extending over very long periods, with most expensive and elaborate instruments. Differential operations have therefore been resorted to instead of absolute determinations; the chronometric method of deducing differences of longitude has been frequently employed, and with very valuable results

wherever it has been practicable to employ a large number of chronometers, and to transmit them backwards and forwards repeatedly by sea; but on land this method is not satisfactory because of the jolting to which the chronometers are more or less subjected in transport from station to station, and which necessarily tends to alter their rate and affect their performances. When however places are connected telegraphically, their differences of longitude can be determined with great precision; and thus of late years advantage has been taken of the nets of wires which overspread large portions of Europe and of America, to determine differences of longitude with the aid thus afforded. In America these operations were required for geographical purposes only; but in Europe, which is covered with a net of triangulation of which there is as yet no counterpart beyond the Atlantic, and which amply suffices for geographical purposes, their chief interest lay in their value for geodetic investigations, and they were undertaken mainly with the object of throwing light on the figure of the earth.

(66.) Exactly eleven years ago I obtained the sanction of the Secretary of State and the Government of India to a recommendation which I had submitted sometime previously that a set of first class instruments, with all the latest improvements, should be constructed in Europe and sent out here to be used for geodetic operations in connection with the triangulation of this survey and the Government lines of telegraph. In the year 1863 Colonel Strange was appointed by the Secretary of State to design and superintend the construction of the requisite instruments, or to procure such instruments as had already been constructed and were suitable for the purpose.

(67.) In 1871-72, the following instruments were received in this country; two transit instruments of 5 inches effective aperture and 5 feet focal length, designed by Colonel Strange and constructed by Messrs. Cooke and Sons of York; two astronomical clocks, by the Messrs. Frodsham of London; two chronographs designed by Mr. Foucault and constructed in Paris by Messrs. Secretan and Hardy; also various relays, batteries and other electrical apparatus.

(68.) I determined to employ these instruments, in the first instance, on the arc of parallel which crosses the southern peninsula in latitude 13°, and extends from Madras on the east to Mangalore on the west coast, passing through Bangalore about midway. There are telegraph stations at each of these places, and great facilities for communication between them, Madras being connected with Bangalore by a direct line of railroad, and with Mangalore by the railroad to the port of Beypore on the west coast, between which and the port of Mangalore steamers are constantly plying. These were very important advantages to secure at the commencement of operations the early stages of which would necessarily be of a tentative and experimental nature, for every thing had to be learnt of the capabilities of the instruments and the telegraphic lines by which the stations of observations would be connected, and thus it was most desirable that the operators should be able to meet each other readily, to discuss and elaborate their programme of operations, and also to compare their personal equations.

(69.) The arc of parallel which was selected, for the preceding reasons, as that on which to commence the electro-telegraphic determinations of longitudes, is moreover of peculiar interest in that it is situated much nearer to the equator than any similar arc which has yet been measured in any part of the globe, or is likely to be measured for many years to come, for such operations must necessarily be restricted to Europe and India until other regions have been trigonometrically surveyed as they have been. The arc may be deemed a short one, and terminating as it does at both ends on oceans it is obviously incapable of extension; yet its length is 5° 24′ 12″ or about 364 miles, which is by no means insignificant, though it is small in comparison with the lengths of the arcs which will be measured hereafter in Central and Northern India. Moreover it was on this arc of parallel that Colonel Lambton first endeavored, in the years 1802-5, to determine the length of a degree of longitude by the method of observing the astronomical latitudes and azimuths of a series of reciprocating stations along it, a method which—though ill adapted to low latitudes—was the only one then feasible for him to employ.

Thus it will be seen that circumstances have necessitated the selection of the same parallel of latitude for the commencement of the determination of longitudinal arcs, by the modern electro-telegraphic method, that was chosen at the commencement of the present century by Colonel Lambton for his corresponding investigations.

(70.) When the requisite instruments arrived in this country they were forwarded to Bangalore, where Captain J. Herschel, R.E., and Captain W. M. Campbell, R.E., were quartered. As both these officers had been employed for several years in astronomical operations, and Captain Campbell had spent several months in the office of the India Store Department in London, in assisting Colonel Strange to examine the instruments on their receipt from the makers, I selected them to carry out the operations, and I have every reason to be gratified with the manner in which they have accomplished the duty assigned to them.

(71.) They commenced proceedings by setting up the two sets of instruments at a distance of about fifty feet apart, in the compound of a house at Bangalore, to test their performances, and at the same time to acquire a practical familiarity with their manipulation; this work occupied nearly two months of the field season. In January the instruments were dismantled and removed; one set was taken to the north the other to the south end of the base-line which had been measured in the vicinity of Bangalore in the year 1868; a temporary telegraph line had been previously erected to connect the ends of the base, the length of which is nearly 7 miles; thus an opportunity was afforded of taking observations at stations sufficiently remote from each other to present difficulties similar to—though not quite so great as—those which would eventually be met with on long lines, but yet close enough to permit the operators to meet each other daily for the purpose of comparing their results and making such modifications as were found to be necessary from time to time; moreover as the stations of observation were also stations of the triangulation, the results would be valuable eventually for determinations of differences of local attraction on the prime vertical, as well as for the primary object of experimenting. The month of February was devoted to observations at the stations at the ends of the Bangalore base-line, during the first half of which Captain Herschel operated at the south end and Captain Campbell at the north end, while during the second half their positions were reversed.

PERSONNEL.

Capt. J. Herschel, R.E.,	Depy. Supdt.	2nd	Grade.
„ W. M. Campbell, R.E.,	„	3rd	„
Mr. G. Belcham,	Asst. Surveyor,	1st	„
„ J. Bond,	„	2nd	„

(72.) In the following month operations were commenced on the line Madras to Bangalore. The station of observation at Madras was the well known Government Observatory which has been established there for so many years and is the point to which the longitudes of the stations of this survey have invariably been referred; at Bangalore the station was the south end of the base-line, which had been connected for the purpose with the Government telegraph lines, as the Madras Observatory had been many years previously.

(73.) And now for the first time Captains Herschel and Campbell found themselves hampered with the difficulty of employing a telegraphic wire which could only be placed at their exclusive disposal for a few periods and those very brief. Though the operations were invariably performed during the night, when the ordinary traffic on telegraph lines is comparatively little, it was found that the unrestricted use of a wire could, as a rule, be only conceded for four periods of fifteen minutes each, at intervals of two hours apart; on two nights however the use of the wire was granted for two hours at a time, but the then unfavorable state of the weather at Madras prevented this concession from being taken to account there. Under the circumstances it was fortunate that the operators had already acquired, from their previous experiments, a sufficient familiarity with the details of the operations to enable them to make the most of the golden moments thus charily presented to them.

(74.) The operations at Madras were conducted by Captain Campbell, and on their completion in April, he proceeded with his instruments to Mangalore,

established an observatory at the trigonometrical station in the neighbourhood, and connected it by a temporary line of telegraph with the permanent line which passes through the town, at a distance of about three quarters of a mile. The operations at the Bangalore Station were conducted throughout by Captain Herschel.

(75.) In the Narrative Reports of Captains Herschel and Campbell—which are printed in the appendix—full details will be found of the procedure of the operations, as well as minute descriptions of the several instruments employed, with elaborate criticisms of their performances which point out both their defects and their good qualities. It is unnecessary for me to do more in this place than to give a brief summary of those reports.

(76.) Two methods of procedure were adopted, depending on the length of time for which the exclusive use of the Government telegraph line could be secured. When the period was limited to a quarter of an hour at a time, signals were interchanged for clock comparisons four times nightly, *viz.*, at $8^h\ 30^m$, $10^h\ 30^m$, $12^h\ 30^m$, and $2^h\ 30^m$; the clock at one station being placed in communication with the chronograph at the other station was made to transmit a series of signals—at successive seconds—to that station, which were duly recorded on the chronograph; then the clock at the second station was made to transmit signals to the chronograph at the first; one minute was considered the minimum duration of a set of signals, and a complete comparison of both clocks usually occupied from three to five minutes. The clock times were determined by observations of the transits of stars over the meridians of the stations, the same stars being observed at both stations; these observations were taken in the intervals between the signals for clock-comparisons; from 6 to 10 stars were observed in each interval, giving—in a full night's work—complete pairs of observations at both stations to 40 or 50 stars. For this method any star is well suited, whether its place is known or not, provided observations are also taken to a few wellknown stars, to determine the clock rates which are wanted for application to the short interval between the transit of a star over the two meridians, which corresponds to the difference of longitude. This precaution was taken and thus the choice of stars was unrestricted.

(77.) Another method of procedure was adopted on the nights when the exclusive use of the line was granted for a period of two hours; the transit observations for determining the clock times were recorded on the chronographs at both stations, first by the observer at the eastern station as a star passed over his meridian, and a few minutes afterwards by the observer at the western station when the same star reached his meridian; observations were also taken as in the other instance, for local clock rates. Of the two methods pursued this is unquestionably the most satisfactory, but it could only be employed very partially.

(78.) The operations would thus appear to be very simple and easy, and they may in truth be carried out with little trouble when the object aimed at is solely to obtain determinations of differential-longitude of a sufficient degree of accuracy for ordinary geographical purposes. But the requirements of geodesy necessitate that the utmost attainable accuracy and precision shall be secured in every stage of the operations for the solution of the problem; and this entails a careful scrutiny of all the facts of observation, and an elaborate examination of the errors which may arise from defects in the several portions of the instrumental apparatus, as well as from the "personal equations" of the operators. These errors are all very minute, and some of them are very difficult to measure and to eliminate from the observations, but they must be investigated and eliminated, or the final results will not be entirely trustworthy. They were chiefly met with in the performances of one of the transit instruments and one of the chronographs, in the management of the chronographic record, and in the transmission of signals along the line; but the determination of the personal equations of the operators was singularly satisfactory, though it happens to be the weak point of all electro-telegraphic longitude observations in Europe and America of which I possess the details.

(79.) The two transit instruments are of almost identical dimensions and were both made by Messrs. Cooke & Sons; but No. 1 was constructed partially

or wholly—it is uncertain which—of aluminium bronze, and No. 2 of gun metal throughout. No. 1 appears to be faultless; but No. 2 is defective, and liable to a kind of flexure—occurring either in the tube or in the axis—which causes the horizontal collimation to vary considerably with the direction of motion of the telescope, the collimator readings being 1″ greater when the telescope is brought down from the zenith than when it is raised up from the nadir. The two chronographs are called **A** and **B**; they are apparently precisely similar in construction, but the regulator of **B** has a uniformly continuous action, whereas that of **A** acts by jerks; the fact was known to the makers but they failed to trace the cause, which is still undiscovered; the result is that **B** is considered "a miracle of regularity" while **A** is pronounced "very provoking."

(80.) The chronographic record consists of a mark made on the paper covering the revolving barrel by the passage through it of an electric spark of high tension, which is generated in a Ruhmkorff's coil by the interruption of a strong galvanic current from a Bunsen battery. Both the clock-beats and the observer's signals are thus recorded on the paper. The electric sparks pass into the paper from the points of two pens or styles—one in connexion with the clock, the other with the observer's tappet—which are attached to a frame that moves parallel to the revolving barrel. To each Ruhmkorff's coil a relay and a battery is attached. Two galvanic circuits are formed, one connecting a primary battery, a relay and its battery and coil with the clock and chronograph, the other connecting a similar apparatus with the observer and the chronograph. Signals are in all instances caused by a break of the current from a primary battery, which is performed automatically by the clock and at will by the observer.

(81.) The introduction of a relay necessarily causes a certain amount of retardation between the generation of a signal and its record on the paper, the magnitude of which is mainly dependent on the adjustments of the armature of the relay through which the current is passing, and as two relays must be employed errors may be caused by differences in their action. Fortunately such differences are susceptible of being accurately measured on the chronograph-barrel, by special operations for the purpose which are described in para. 33 of Captain Campbell's report; but it is necessary that a strict similarity of circumstances to what obtained during the actual signals should be maintained during the measurement of retardation. Captain Herschel writes that "constancy of "current is the *sine qua non* of a correct handling of retardation; *ergo* equality "under these circumstances must be attained; every relay must have its own "battery, and these must all be equal; and the line must have a battery of its "own so apportioned that the long circuit current shall balance the short circuit "current."

(82.) The line wires between the stations at Madras, Bangalore and Mangalore were connected continuously without the intervention of relays; thus the difficulties presented by relays were fortunately restricted to the observatories, where alone it was possible to measure and allow for the amount of retardation which was generated.

(83.) It was surmized that in transmitting currents along the line wires there might be a difference between the velocity of transmission of positive and of negative currents, and that the presence of earth currents might affect the velocities of the galvanic currents, accelerating in one direction and retarding in the opposite. The following values of the actual times of transmission of positive and negative currents, in both directions, were obtained on the two sections of the line, the length of wire in the eastern section being 218 miles, in the western 245 miles.

	Madras to Bangalore	Bangalore to Mangalore.
From east to west with positive current,	0·010 *second*	0·028 *second*
„ west to east „ „	·010 „	0·022 „
„ east to west „ negative „	·014 „	0·003 „
„ west to east „ „ „	·014 „	0·011 „

These results show that no sensible influence, in one direction more than the other, was exerted by earth currents. The velocity of the positive galvanic current was

somewhat greater than that of the negative in the eastern section, but materially less in the western. Captain Campbell attributes some of the large difference in the latter instance to relay action.

(84.) The general mean of all the determinations gives a velocity of 17,000 miles per second, which is materially greater than the velocities deduced in the course of similar operations in Europe and America; as however several relays were used on those lines and none on these, such a difference is only what might have been anticipated.

(85.) It will be apparent from what I have stated that Captains Herschel and Campbell have conducted their operations with scrupulous care, and devoted themselves to the elimination of all errors, however minute, which were liable to be generated. From their reports it will be seen that they met with great difficulties in the manipulation of the Foucault-chronographs; these instruments are of a very complicated construction; moreover the recording paper on the barrels requires to be kept at a certain degree of moistness, and if it is either a little too dry or little too damp the electric spark fails to make a mark on it; its state is therefore greatly dependent on that of the atmosphere; thus in the dry climate of Bangalore in February, Captain Campbell could scarcely keep his paper damp enough, whereas a week afterwards, at Madras, he was obliged to have a lamp burning under it to prevent it from being too damp.

(86.) The employment of chronographs permits of a large number of observations being taken with very little additional trouble at the time, as compared with a corresponding increase in the number of 'eye and ear' observations. But on the other hand the subsequent labor of reducing the observations is greatly increased, for every mark on the paper has to be measured and its position tabulated numerically. Up to the present time the observations on the line Bangalore to Mangalore have been reduced as far as practicable, but they may still require certain corrections for the flexure of transit instrument No. 2; those on the line Madras to Bangalore and on the base-line at Bangalore have only been partially reduced.

(87.) The following preliminary results have been obtained, which will probably be found not to differ very materially from the final results. For the sake of comparison they are placed side by side with the corresponding differences of longitude obtained from the chain of triangles recently completed by Major Branfill.

		Telegraphic.			Trigonometrical.		
		h.	m.	s.	h.	m.	s.
I.	Madras to Bangalore, ...	0	10	39·09	0	10	39·61
II.	Bangalore to Mangalore, ...	0	10	56·76	0	10	57·17
	Madras to Mangalore, ...	0	21	35·85	0	21	36·78

The telegraphic determinations are in both instances less than the trigonometrical, on the first section by 0″·52 (second of time), on the second by 0″·41, and on the entire line by 0″·93, which is equivalent to 13″·95 (seconds of arc.)

(88.) The values of the individual sections of the telegraphic arc are somewhat impaired by reason of the defects of transit instrument No. 2 and chronograph A which have already been mentioned. But as those instruments were used at the central station throughout, while the superior instruments—transit No. 1 and chronograph B—were used at the two end stations, the errors in the sections must cancel each other to a considerable extent in the determination of the entire arc, the value of which may be legitimately compared with the corresponding trigonometrical determination.

(89.) The latitudes and longitudes of the stations of this Survey have for the last forty years been computed with the following elements of the figure of the earth, which are generally known as Everest's first set of Constants, and are given at page 115 of the *Account of the Measurement of an Arc between the Parallels of* 18° 3′ *and* 24° 7′, *London* 1830;

equatorial semi-axis 20,922,932 feet; ellipticity $\frac{1}{300{\cdot}80}$.

Subsequent investigations have slightly modified these dimensions of the mean figure, and Captain Clarke gives the following elements in the appendix to his *Comparisons of the Standards of length, London* 1866;

equatorial semi-axis 20,926,062 feet; ellipticity $\frac{1}{294\cdot98}$.

(90.) Using Captain Clarke's elements instead of Colonel Everest's, the trigonometrical determination of the difference of longitude between Madras and Mangalore would be diminished by 3″·5, and thus be brought into better accordance with the telegraphic difference, which however it would still exceed by 10″·5. There is at present little reason to suppose that further investigations of the mean figure of the earth, or corrections to the telegraphic determination, will very appreciably reduce this difference. We are thus met by the fact that the telegraphic value of the arc of longitude between Madras and Mangalore is materially less than the trigonometrical value. This fact is however consistent with the results of Captain Basevi's pendulum observations, which show that the density of the strata of the earth's crust is greater under the depressed beds of oceans than it is under lands elevated above the sea level; thus the direction of the plumb line at Madras, on the east coast of the continent, is most probably deflected to the east of the normal to the mean figure, while at Mangalore the direction of the plumb line is deflected to the west of the corresponding normal; the length of the arc between the apparent zenith points is consequently diminished and must therefore be less than the length deduced from trigonometrical operations.

(91.) Captain Herschel having been compelled to take leave of absence to Europe shortly after the completion of the observations, the work of reduction has devolved mainly on Captain Campbell, who has reported very fully on it, and has also described very minutely the instruments, the *modus operandi* and the difficulties which were met with in the several stages of the operations.

(92.) Captain Campbell bears grateful testimony to the attention and courtesy which were rendered to him, on all occasions, by the officers of the Telegraph Department with whom he was brought into contact, mentioning more particularly Messrs. J. Burke and W. P. Johnston; and he adds that his best thanks are also due to Mr. Pogson, the Government Astronomer at Madras, who took a pleasure in facilitating his operations in every possible way.

No. XI.—GEODETIC.

ASTRONOMICAL DETERMINATIONS OF LATITUDE.

(93.) The observations to determine the astronomical latitudes of certain stations of this survey for geodetic purposes were held in abeyance during the present year, as the two astronomical parties under Captains Herschel and Campbell, by which they had been carried on, were both employed on the longitude observations which have just been described. The reductions of the observations of the previous year which were remaining in hand have however been completed, and Captain Campbell has devoted much attention to investigating the cause and the effects of a serious defect which has been found to exist in zenith sector No. 2, and is of the nature of flexure in the tube of the telescope. The cause has not yet been clearly traced, but the effects are found to be very sensible, and the value of the results might have been materially impaired but for the precaution which had fortunately been taken to observe pairs of north and south stars, whereby the influence of the error was eliminated. The sister zenith sector No. 1 has fortunately shown no trace of this error, and has given great satisfaction to Captain Herschel. It is a singular circumstance that one of the two zenith sectors, as well as one of the two transit telescopes, should turn out to be defective, while the other instrument of the pair is entirely satisfactory, and there is no apparent difference of construction which could cause the difference of performance.

No. XII—GEODETIC.

THE PENDULUM OPERATIONS.

(94.) Captain Heaviside, having been nominated to complete the pendulum operations which were suspended in consequence of the death of Captain Basevi, was employed for some time in acquiring a knowledge of the manipulation of the pendulums and the reduction of the observations. He then commenced operations by swinging the two pendulums appertaining to the Royal Society at Kaliana—the base-station of the operations in India—to ascertain whether they had varied in length since they were swung there in 1870, before being taken to the higher Himalayas by Captain Basevi. This was the more necessary in that on the occurrence of the sudden death of that officer, at a remote spot on the elevated table lands of Ladak, they had to be dismantled and packed up by his native servants, without supervision of any kind, no European being within a distance of several marches; that these men did their work carefully and well is shown by the fact that the results obtained by Captain Heaviside at Kaliana, are practically identical with those obtained by Captain Basevi nearly three years previously, which proves that the pendulums cannot have met with any sensible injury in the interim.

PERSONNEL.

Captain W. J. Heaviside, R. E., Deputy Superintendent 3rd Grade.
Mr. H. E. Keehn, Surveyor 3rd Grade.
„ J. W. Macdougall, Asst. Surveyor 2nd Grade.

(95.) This fact established Captain Heaviside proceeded to complete the original programme of operations, swinging the pendulums at Bombay, at Aden, in Egypt, and finally at Kew the base-station in England.

(96.) Simultaneously with the observations with the Royal Society's pendulums, Captain Heaviside has taken observations with the pair of pendulums belonging to the Russian Imperial Academy of Science which were sent out to India in 1870 for the purpose of being compared with those of the Royal Society. The Russian pendulums may be employed to determine either an absolute value of the length of the second's pendulum, or differential values of the force of gravity at different places. Absolute determinations have been made at Kaliana and at Kew, and differential ones at Bombay, Aden and Ismailia.

(97.) Captain Heaviside, when last heard from, was still in England and was preparing to repeat the determination of the length of the second's pendulum, with the same "convertible pendulum" which had been used for this purpose by Captain Kater in 1817, and which has been placed at his disposal by General Sir E. Sabine. This undertaking will form a very appropriate finale to the operations. On its completion, Captain Heaviside will return to India, and commence the final reduction of the several observations, in order that the results may be published as soon as possible.

No. XIII.—TIDAL.

DETERMINATIONS OF MEAN-SEA LEVEL.

(98.) In my administration report for 1866-67 I stated that proposals had emanated from Dr. Oldham, the Superintendent of the Geological Survey, and been sanctioned by the Government of India, to the effect that investigations should be made of the secular changes in the relative level of land and sea which were believed to be going on at various places on the coasts of the Bombay Presidency and more particularly at the head of the Gulf of Cutch. For these investigations it would be necessary to take complete series of tidal observations, at intervals of a few years apart, at a certain number of points on the coast lines, and to connect these points by very carefully executed lines of levels. I was

called on to undertake the operations, and I had procured a number of self-registering tide-gauges from England and was about to have them erected and the work commenced, when I was suddenly required to take steps for an immediate and very considerable reduction of expenditure, in consequence of the financial difficulties in 1869-70 ; the operations were therefore postponed *sine die*. They are now being resumed.

(99.) The delay which has thus taken place is not to be regretted, as I am now in a position to have the investigations carried on in a more complete and elaborate manner than had been originally contemplated, and consequently to acquire fuller, more comprehensive and more accurate results than were at first desired. Happening to be present at the meeting (at Edinburgh) of the British Association for the Advancement of Science, in 1871, I ascertained that a committee of the association—presided over by Sir William Thomson—had initiated a system of tidal investigations which was anticipated to secure scientific results of the highest value. On studying the details of these operations I found that my original programme, which contemplated tidal observations of only a few week's duration, would be inadequate to detect the existence of minute secular changes in the relations of land and sea, and that no conclusive results could be obtained unless the observations were carried over a period of rather more than a year at the commencement and a corresponding period at the close of the term of the investigation. I further saw that if this were done the value of the operations would be greatly increased, for the results would not only serve the purpose for which they were originally contemplated, but would materially contribute towards the attainment of the better knowledge of the laws of the tides which is considered by the British Association to be so important a desideratum, and which is expected to lead to an evaluation of the mass of the moon, to definite information regarding the rigidity of the earth, to an approximation of the depth of the sea from the observed velocities of tide-waves, to the retardation of the earth's rotation due to tidal friction, and also to the various practical benefits which must accrue from accurate predictions of the height of the tide at any given time.

(100.) For these reasons I submitted a proposition to the Secretary of State that Lieutenant Baird R. E., Assistant Superintendent, who was then in England on furlough, should be deputed to study the practical details of the method of tidal registration, and of the harmonic analysis of the observations, which are recommended and practised by the tidal committee of the British Association. My proposals were sanctioned and Lieutenant Baird was employed for some months under my directions in doing what was wanted.

(101.) Mr. Adie—the well known optician and mathematical instrument maker—had constructed the self-registering tide-gauges which had been previously sent out to India, and of which the most remarkable feature is their unusually long barrels (length five feet) which were provided in order that the tidal curves might be drawn on the largest scales practicable; he was requested to supply another tide-gauge on the same pattern but with a few modifications which appeared desirable, the most important of which was the substitution of a chronometer escapement instead of a pendulum or gravity escapement for the driving clock, in order to permit of the instrument being erected on positions where the concussions of the sea-waves would interfere with and perhaps stop the action of a pendulum clock. Lieutenant Baird made an experimental trial of the performances of this tide-gauge at Chatham, the results of which were very satisfactory.

(102.) It is well known that the rise and fall of the tides on a line of coast is materially influenced by the direction and force of the winds, and that it also varies inversely with changes in the barometric pressure. Thus no tidal registrations can be deemed complete without simultaneous registrations of the conditions of the atmosphere. Consequently a supply of self-recording anemometers and barometers was obtained, in order that every tidal station should be supplied with one of each of these instruments. The anemometers register both direction and velocity, and are similar in design to Beckley's anemometer, but

are very much smaller in order to be light and portable; the barometers are aneroids, for no mercurial self-registering barometers were met with which could be safely carried about. These instruments were all constructed under my instructions by Mr. Adie, and though they are by no means faultless they may be relied on to give fairly approximate results which will be of some value and vastly better than nothing at all. Mr. Adie has also supplied other instruments which will materially facilitate the preparation of the diagrams for the barrels of the tide-gauges and the subsequent measurements of the curves on the diagrams.

(103.) One of the principal duties on which Lieutenant Baird was employed in England was the preparation of an account of the practical application of the harmonic analysis by which tidal observations are reduced for the British Association. The procedure leads to much more definite and conclusive results than what are afforded by any other method of reduction, but it is exceedingly intricate; though perhaps not more laborious in the long run than other methods would be, when manipulated so as to furnish results of equal precision and bearing on such a wide range of subjects, it needs very full and precise explanations for the guidance of the computers. Lieutenant Baird went through the whole of the details with Mr. Roberts of the Nautical Almanac Office by whom the tidal reductions are made for the British Association; and with that gentleman's aid he drew up a pamphlet of Notes on the subject, for the use of the Officers of this Department, which has been published by order of the Secretary of State, and fills 51 pages of closely printed octavo.

(104.) On my return to India I deputed Lieutenant Baird to make a reconnoisance of the coasts of the Gulf of Cutch, with a view to selecting tidal stations and more particularly to determine in what manner the instructions which I had received from the Government to establish a station "at a point as far into the Runn of Cutch as possible to which the tide has free access," could be best carried out. For a point to have free access with the sea it is necessary that it should always have at least 4 or 5 feet of water at lowest tides, and also that the sea should approach it directly and not through tortuous channels; the point must also be either on the edge of the main land or at no great distance beyond, because of the difficulty and expense of constructing a station on the fore-shore. From what I had previously heard of the Gulf of Cutch I was apprehensive that it might not be possible to find a point at the edge of the Runn which would satisfy all the requisite conditions.

(105.) Lieutenant Baird proceeded in the first instance to Júria Bandar (Jooria Bunder), where he fitted up a large country boat to be used in navigating the creeks and channels of the gulf, and secured the services of a good pilot to accompany him in his explorations; the selection turned out to be a very fortunate one as the pilot knew almost every creek and mud-flat on both the Cutch and the Kattywar coasts of the gulf. Embarking at Júria, Lieutenant Baird crossed to Nowanár Point on the Cutch coast, where he found a spot which is well adapted for tidal observations, having a minimum depth of 19 feet of water within 336 feet of a site for a station. He then proceeded eastwards towards the head of the gulf, along a coast which for a considerable distance presents a great breadth of fore-shore—composed of mud of great depth with mangrove bushes growing over it—and is covered at high tide and left bare at low water. After long searching he was fortunate in discovering a position near Hanstál Point, at the head of the gulf, which is well adapted for a tidal station, having a minimum depth of 72 feet of water within 160 feet of a site for an observatory. Lieutenant Baird then returned westwards along the Kattywar coast, examining all the creeks and inlets, and finding nothing but long muddy fore-shores, until he reached Okha Point at the entrance to the gulf; there he met with a rocky fore-shore having a minimum depth of 23 feet of water within 220 feet of a site for a tidal station. The three places selected appear to be well adapted for the proposed operations, which is the more fortunate in that Lieutenant Baird believes them to be the only suitable points which are to be met with for the purpose; the only matter for regret is that an intermediate point could not be found on the Kattywar coast

between Okha and Hanstál, for Nowanár being on the opposite coast will require to be connected with the two other stations by a very long line of levels passing round the head of the gulf.

(106.) Lieutenant Baird derived much assistance in his explorations from the admirable charts which were constructed by Lieutenant A. D. Taylor of the Indian Navy, in 1851, copies of which, on the full scale of the original survey, had been recently lithographed in England on my recommendation.

(107.) The feasibility of establishing stations at suitable points having been thus satisfactorily ascertained, the preliminary arrangements were then taken in hand. The question whether it would be preferable to set up the tide-gauges on stages erected in the sea beyond the low water line, or on masonry platforms constructed on shore at the high water line, was carefully considered; obviously it is desirable that the communication between the surface of the ocean and the gauge which registers the momentary variations of level should be as direct as possible, in order that the tidal curve may be accurately delineated; but it would be impossible, without incurring great expense, to construct a staging in the sea of sufficient strength and permanence to serve for two series of observations, each lasting more than a year and separated by an interval of several years. For this reason it has been decided to construct the stations on shore, at the line of high water.

(108.) The following arrangement has been adopted. Masonry wells of a diameter of about three feet will be sunk at the stations to a depth of several feet below the lowest tides; in these wells iron cylinders, of a diameter slightly exceeding that of the float of the tide-gauge, will be set up vertically and eventually connected with the sea by an iron piping carried along the shore down to the low water line, where a flexible piping will be attached and carried into deep water. The cylinders will be closed below with an iron plate, to prevent the entrance of the water which may be expected to percolate through the sides of the well whenever the tide is falling. The flexible piping will terminate in a rose suspended a few feet above the bed of the sea, in order to prevent the entrance of silt as much as possible, and it will be attached to the iron piping in such a manner that it may be readily removed and cleaned whenever necessary. The interior diameter of the piping will be two inches, which has been computed to be sufficient to permit of the transmission of the tidal wave from the sea to the cylinder in the well, without sensible retardation, so that the height of the water in the cylinder may be expected to be always the same as that of the surface of the sea. The tide-gauges will be set up over the cylinders, and their iron bed-plates will indicate the planes to which the tidal measurements will be referred, and they will be connected by leveling with permanent bench-marks fixed in the ground in the vicinity of the stations.

(109.) Lieutenant Baird has been employed during several months at Bombay in making all the requisite arrangements. Cylinders have been constructed in suitable lengths to be easily transported to the tidal stations and then put together. The tide-gauges have been tested by employing them to register the tides in the harbour of Bombay for several weeks continuously, and sundry alterations and improvements have been made to them. The self-registering barometers and anemometers were tested at the same time, and the injuries they had received in transit out to this country and from the rusting of portions of the working gear have been repaired. Every thing has been done which could be thought of to ensure the instruments being found in a satisfactory condition when they are set up for work at the tidal stations. It was a matter of great importance to have all this done at Bombay, where there are excellent workshops and skilled artificers, for such advantages are not to be met with in the places where the instruments will be set up for observation. In all these operations Lieutenant Baird received much assistance from Major Merewether R.E., who permitted him to have full use of the workshops and artificers of the Bombay Harbour Defences, and allowed him a site for testing the tide-gauges.

(110.) Lieutenant Baird is now engaged in constructing the stations on the coasts of the gulf of Cutch, and when they are ready the observations will be commenced. He has worked with great assiduity and skill, and with a hearty interest which I trust will be rewarded in due time by the successful completion of the operations.

NO. XIV.—GEOGRAPHICAL.

TRANS-HIMALAYAN EXPLORATIONS.

(111.) For some years past it has been customary to publish with the annual Reports of this Survey an account by Major Montgomerie of one or more special explorations executed by his native agents. Ill health has unfortunately deprived the State of the services of this officer, but I trust for only a short time; he has gone to Europe, taking with him the maps and journals of an exploration—by one of the Pundits—from Shitgatzé north-eastwards to the great Namchú Lake, and then southwards to Lhassa, of which he was to have prepared an account for publication with this Report; but as it has not yet been received it must be published separately hereafter.

(112.) Explorations are being carried on at the present time in various directions. A Pathán has been sent to the region beyond the Hindú Kúsh range, with instructions to penetrate if possible into the *terra incognita* to the north of the river Oxus, into Shighnán, Roshán, Darwáz and Kárategin. One of the Pundits has been sent into the part of Great Thibet which lies beyond the northern watershed of the Brahmaputra River. Four of the Pundits have been attached to the Mission which has been recently sent into Eastern Turkestan, in the expectation that they may be able to make their way back to India by various routes through the Desert of Gobi and Great Thibet which are closed to Europeans.

(113.) I very much regret to state that intelligence has been received of the murder of the Mirza, whose exploration of the route from Badakshan across the Pamir steppe to Kashgar is described by Major Montgomerie in a paper accompanying my Report for 1869-70, and is a valuable contribution to the geography of those regions. The Mirza had been sent on a second exploration with his son-in-law as an assistant. He had to travel through Afghanistan and at first he was able to send in reports of his progress pretty regularly; but for several months he had not been heard of, and at last a rumor was received that he had been murdered. Enquiries have been instituted, but as yet no very definite information has been obtained. It appears probable however that he had traversed the road from Herat to Maimana, and was proceeding northwards, when he and his companion were murdered by their guides during the night while asleep; a servant is said to have escaped and given information which led to the apprehension and subsequent execution of the murderers, by order of the Governor of Maimana. At first there was reason to hope that the rumor might have been unfounded; for the Mirza was believed to have been exploring in the direction of Hissár and Kárategin, far away from the place where the crime is said to have been committed; but as no letters have been received from him for nearly a year, and he would probably have returned some months ago had he lived, it is to be feared that this faithful and intelligent emissary has fallen a victim, and that his son-in-law who accompanied him perished at the same time. Endeavors are being made to obtain full information on the subject, and to get possession of any of the Mirza's papers which may be still forthcoming.

(114.) Enquiries are being made with a view to secure the services of a few natives of Assam who are privileged to enter the hills north of the valley which are occupied by independent tribes, with a view to training them to make explorations in those hills in the first instance and afterwards in the regions beyond, and more particularly to make a survey of the portion of the Brahmaputra River which as yet has not been explored. The replies which have hitherto been received from the district officers show that there will be great difficulty in getting suitable persons for the explorations, but I still hope that it may be managed by Mr. Beverley, who is conducting the triangulation of Assam and has been requested to take this matter in hand.

(115.) But the quarter from which I have most reason to expect soon to receive valuable and exact geographical information is Eastern Turkestan. On learning from Mr. Forsyth that he was about to be deputed on a mission to the Atalik Ghazi, I strongly urged the necessity of his being accompanied by an Officer of this Department, to undertake the duties of a geographer and turn to account any opportunities which might be presented of exploring regions of which little or nothing is at present known. Mr. Forsyth cordially entered into my views, and supported the proposals which I submitted to the Government of India, by whom they were favourably received. Captain Henry Trotter, R.E., who was then conducting the Survey of Kattywar, was consequently placed at the disposal of the Foreign Department and appointed a member of Mr. Forsyth's Mission. Pending the return from Constantinople of the Atalik Ghazi's Envoy who was to accompany the Mission, Captain Trotter spent some time at my head-quarters in practising such astronomical observations as would be required, and more particularly those for the determination of absolute longitudes; forms were prepared and printed for facilitating the reduction of the observations, in order that they might be computed out on the spot and immediately utilized in the construction of a map of the country, because far more comprehensive and satisfactory results should thus be obtained than when the observations are reduced and the map constructed some time afterwards. Captain Trotter was well equipped with instruments, all of which are of the lightest and most portable kinds suited to his requirements, and he was furnished with charts on which the fixed points of the Indian triangulation to the south and the Russian astronomical determinations to the north had been projected, to facilitate his own operations in the intervening region. Two other officers attached to the Mission, Captain Chapman, R.A., and Captain Biddulph, A. D. C. to the Viceroy, spent a short time at my head-quarters in practising observations and reductions, with a view to utilizing any opportunities which may be presented should they be detached from the head-quarters of the Mission on independent explorations. A Kashmiri surveyor—of the Rajputana Survey—and four of the Pundits have been sent with Captain Trotter. I have done all in my power to promote the success of the geographical operations, and in my next annual report I hope to be able to announce that a rich harvest of results has been secured.

NO. XV.—THE COMPUTING OFFICE.

EXAMINATION, FINAL REDUCTION AND PUBLICATION OF THE OBSERVATIONS.

116. The Computing Office has been employed in its usual duties of carefully examining and reducing the observations, and publishing the ultimate results of such portions as have been finally treated and the preliminary results of the pro-

PERSONNEL.

J. B. N. Hennessey Esq. Depy. Supdt. 1st Grade
W. H. Cole, Esq., Asst. Supdt. 1st Grade

Computing Branch.

Mr. C. Wood, Surveyor 3rd Grade
„ H. W. Peyclers, Asst. Surveyor 1st Grade
Baboo Gunga Purshad, Computer
„ Cally Mohun Ghose, Computer
„ Kally Coomar Chatterjee, Computer and 11 other Native Computers

Printing Branch.

Mr. M. J. O'Connor
and 18 Native Compositors and Distributers

Photozincographic Branch.

Mr. C. G. Ollenbach
„ C. Dyson, with 2 Native Draftsmen &c.

Drawing Branch.

Mr. G. W. Atkinson, Surveyor 4th Grade,
Shaikh Saidudeen and 5 Native Draftsmen also 18 Assistants and Apprentices

tions which await further data before they can be finally disposed of. One of the principal features of the year's labors has been a re-adjustment of the secondary triangulation which is based on the several principal series appertaining to the so called North-West Quadrilateral, which embraces the operations of this Survey in the area lying to the north of a line running westwards from Sironj (in Central India) to Kurrachee, and to the west of a line running from Sironj to the Himalayas. Another important operation is the passing through the press of the observations, reductions and final results of the principal triangulation of the North-West Quadrilateral, which is now all but completed, and will furnish sufficient matter to fill two thick quarto volumes which will be numbered III and IV of the *Account of the Operations &c.*

117. As the whole of the contents of these volumes will not be needed by geographers and surveyors, an abstract or synopsis is being prepared which will give the descriptions and co-ordinates of the stations, and the sides and angles of the triangles, of the principal triangulation, and also the corresponding data of the secondary triangulation. This information will be published in a separate volume for each of the principal series, in which form it will be most convenient for the public in general. The first of these synopses is now nearly ready for issue; it is devoted to the operations of and emanating from or otherwise connected with the chain of triangles known as the Great Indus Series, and will contain—*inter alia*—the positions of the whole of the points that have been fixed beyond the British Frontier, points situated mostly on the spurs of the Hindú Kúsh range, and on the Safed Koh and Súlimáni ranges and their spurs.

118. The general principles on which the reduction of the observations is conducted have been described in sufficient detail in the annual reports for the last five years which have been submitted by myself and by Major Montgomerie; it is unnecessary therefore for me to say more on the subject in this place than that the operations are very laborious and require constant and vigorous supervision, and that I have every reason to be indebted to Mr. Hennessey for the assiduity with which he devotes himself to the direction of the computing office and its several branches, and to acknowledge the skill which he brings to bear on the many matters which come under his consideration. Mr. Cole also has rendered a variety of most valuable services which I am very pleased to have this opportunity of acknowledging.

NO. XVI.—CARTOGRAPHY.

119. The most interesting of the maps which have been prepared and published during the current year is the second edition of my map of Turkestan, of which the first edition was published in four consecutive sheets in 1867-68. So great has been the progress of geographical exploration in the last five years that

the map had become insufficient for present requirements, and it needed numerous corrections and additions. As the value of a map of this nature—which has necessarily to be compiled from a variety of sources, some very much more reliable than others—is greatly enhanced by a knowledge of the authorities from which the data have been derived, I drew up a memorandum on the subject in a paper which is entitled "Notes on the Maps of Central Asia and Turkestan which have been published in the Office of the Great Trigonometrical Survey of India," and of which copies were issued with the second edition of the map; a copy is also appended to this report. While the map was passing through the press additional information was received of the geography of Khiva and portions of northern Persia which necessitated the publication of an "Addendum" with it. Shortly afterwards further information was received, and consequently Re-prints of sheets No. 1 and 3 have been published, which embody all the latest information received up to the present date. To these re-prints a note has been attached explanatory of the alterations and additions, and a copy of this note is also appended.

(120.) The northern boundary of the territories of the Maharajah of Kashmir has been brought back in the second edition of the Turkestan map to a considerable distance within the line indicated on the first edition of the map, and and in my notes I state that this had been done on the authority of Mr. Forsyth. I had followed the delineation given in the map of Eastern Turkestan which was compiled in the Surveyor General's office in 1871, under Mr. Forsyth's superintendence, to illustrate his report of his first journey to Yarkand; in that map the the altered boundary line is shown, but on the authority—as it now appears—of a map constructed by the late Mr. Hayward, which Mr. Forsyth had furnished to be used in the compilation of his own map, unfortunately without stating that he objected to the alteration. Under the circumstances it is to be regretted that any alteration was made, and that Mr. Forsyth should have been brought forward as the authority for a line of boundary to which he strenuously objects.

(121) During my absence from India Major Montgomerie commenced the compilation of a series of "Trans Frontier Maps," on the scale of 16 miles to the inch, containing all the most recent information of the regions beyond the British Frontier. These maps are prepared on a skeleton form, showing the positions of towns, villages and mountain passes and the course of the river, but omitting the hills. The following have now been published; No. 4, comprising portions of Afghanistan, Kafiristan, Badakshan, Bokhara, Karategin, Swat, Bajour, Panjkora, and Chitral; No. 7, comprising Chilas, Gilgit, Yassin, Kunjut, Sirikul, the Pamir Steppe, Kashgar, Yarkand, Khotan, and part of Chinese Thibet; and No. 9, comprising Nepaul, Sikkim and portions of Bootan and Great Thibet.

(122.) Good progress has been made with the series of Level-Charts on which the results of the leveling operations for Canals, Railways and other public works are shown, after having been connected with the main lines of level of this Survey and reduced to the same datum, *viz.* the mean sea level at Kurrachee. Sheets No. 8, 10, and 23 (see accompanying Index Chart) have been published and No. 6 and 26 are in a very advanced state.

(123.) In addition to the above, twenty preliminary charts of the triangulation in various parts of India have been published, and several final charts are in hand which will be published with the synopses of the results of the triangulation. A large amount of miscellaneous work has been performed, and an improved system has been introduced for the examination of the maps received from the Survey Parties. By the photozincographic process 21,171 copies of charts, maps and diagrams have been printed of which 8,443 have been colored by hand for issue to the public and to Government officials, and 12,549 copies of forms for calculations and office work have been zincographed for the current requirements of the department.

(124.) It now only remains for me to acknowledge the valuable services which have been rendered by my Personal Assistant Mr. H. Duhan, and by Mr. Robert Scott, whose multifarious duties in connection with the corresponding office and as general store-keeper have been very carefully performed.

(125.) An abstract of the out-turn of work executed by each of the survey parties whose work can be exhibited in this form is given on the following page. I am happy to be able to express my opinion that the progress made on all sides during the year, by the Survey Parties in the field and in recess, and by the Offices at Head Quarters, has been generally most satisfactory.

J. T. WALKER, COLONEL, R.E.,
Supdt. Great Trigonometrical Survey.

DEHRA DOON,
Dated 9th January 1874.

Abstract of the out-turn of work executed by the Great Trigonometrical Survey Parties, during the Official year 1872-73.

Description of Details.	1 Bilâspur Meridian S. Sec. 36-inch Theodolite.	2 Bilâspur Meridian N. Sec. 24-inch Theodolite.	3 Assam Valley Triangulation. 12-inch Theodolite.	4 Jodhpore Meridian. 24-inch Theodolite.	5 Mangalore Triangulation. 24-inch Theodolite.	6 Brahmaputra Triangulation. 24-inch Theodolite.	7 Kattywar Survey.	8 Guzerat Survey.	9 Kumaon & Gurhwal Survey.	Total.
Number of Principal Stations, newly fixed, ...	15	8	...	12	17	13	...	...	...	65
Number of Principal Triangles, completed, ...	21	16	...	14	25	16	...	...	...	92
Area of Principal Triangulation, in square miles,	2364	680	...	3706	3330	845	...	...	...	10,925
Lengths of Principal Series, in miles, ...	96	54	...	95	105	56	...	...	...	406
Average Triangular error, in seconds, ...	0·45	0·36	...	0·33	0·65	0·94	...	...	...	...
Average Probable errors of Angles, in seconds, ±	0·16	0·21	...	0·15	0·14	0·29	...	...	...	...
Azimuths of verification, ...	1	1	...	1	2	2	...	...	...	7
Number of Secondary Stations whose positions and heights have been fixed, ...	83	...	51	15	74	1	358	109	82	773
Number of Secondary Stations whose positions only have been fixed, ...	...	...	...	...	...	...	731	19	13	763
Number of Secondary Triangles of which all 3 angles have been observed, ...	108	...	2	15	31	54	244	168	22	644
Length of Secondary Series in miles, ...	...	..	10	...	...	44	...	...	...	54
Area of Secondary and Minor Triangulation in square miles, ...	5075	...	7290	2413	4064	...	2680	791	353	22,696
Number of Points fixed by intersection, but not visited, ...	205	...	56	50	53	15	945	499	66	1,889
Length of boundary lines and check lines surveyed in linear miles, ...	...	...	...	...	...	...	1148	773	573	2,494
Area Topographically surveyed on scale of 1 inch = 1 mile, in square miles, ...	...	...	...	...	...	...	...	...	2734	2,734
„ Topographically surveyed on scale of 2 inches = 1 mile, in square miles, ...	...	...	...	...	...	...	2642	1236	...	3,878
Number of Revenue Survey Stations and boundary pillars, fixed, ...	...	...	3	...	...	1	?	104	41	149
Do. of Principal Stations selected in advance, ...	...	...	8	13	7	...	...	...	...	28
Lengths of Approximate Series, Principal, in miles, ...	...	...	45	147	36	...	...	...	...	228
Number of Towers constructed, ...	...	...	...	...	1	4	...	...	...	5
Do. of Platforms constructed for Principal Stations, ...	2	6	...	25	7	5	...	...	...	45
Do. of Platforms constructed for Secondary Stations, ...	18	...	...	...	7	4	...	...	...	29
Do. Miles of Rays cleared, ...	...	...	89	...	...	34	...	...	481	604
Do. Miles of path-way made, ...	280	12	...	15	14	10	...	...	...	331
Do. Hill tops cleared of forests and jungle,	80	6	2	...	9	...	...	...	43	140
Do. Principal Stations whose elements were computed, ...	13	8	4	22	5·	16	...	...	...	68
Do. Secondary Stations whose elements were computed, ...	9	...	56	102	27	51	?	?	203	451
Do. Preliminary Charts of Triangulation,	1	1	1	1	1	1	...	...	...	6
Do. Principal Stations placed under official protection, ...	30	7	4	...	20	...	...	...	...	61
Do. Stations protected and closed, ...	30	1	4	43	24	13	...	...	...	115
Do. Points whose Longitudes have been determined, ...	...	...	...	...	...	...	.	...	...	...
Do. Aneroid observations for determination of height, ...	...	...	...	...	155	...	?	?	?	155

APPENDIX.

EXTRACTS FROM THE NARRATIVE REPORTS

OF THE

EXECUTIVE OFFICERS IN CHARGE

OF THE

SURVEY PARTIES AND OPERATIONS.

Notes on the Maps of Central Asia and Turkestan which have been compiled and published in the Office of the Great Trigonometrical Survey of India, under the superintendence of Colonel J. T. Walker, R.E.

In the year 1862 I was called on to compile a map of "Asia between the parallels of 20° and 60°" to accompany the Report on the Trade and Resources of the Countries on the North Western Boundary of British India, which was published by the Punjab Government. While thus occupied I realized how very slight and inaccurate was the knowledge then possessed in India of the regions lying between the Russian and the British Frontiers. I went to England in 1864 and found that neither in the India Office nor in the archives of the Royal Geographical Society was any better information forthcoming. It appeared that our knowledge of the Geography of these regions was almost solely derived from the maps which had been compiled in 1711 by the French Jesuits in the service of the Emperor of China, and for which the only data had been "divers very exact journals," "itinerary distances," and the "latitudes and longitudes given in the tables of Nassir Addin, Olug Beig, and other Eastern Astronomers, quoted by Abû'l Feda."* These maps had no pretensions to accuracy and they contained very little detail; and the Messrs. Schlagintweit had recently come to the conclusion, from their own observations, that the positions of Kashgar and Yarkand on the Jesuit's maps were erroneous by 2° in longitude.

(2.) This state of things being most unsatisfactory, I obtained the permission of the Secretary of State for India to proceed to St. Petersburg, to ascertain whether any more accurate and valuable information might be obtained from Russian sources. The Russian Government was known to have recently obtained, by the treaty of Pekin, a grant of land in Kashgar, in Eastern Turkestan, for the erection of a factory; the Russian frontier had been recently carried south-wards into Western Turkestan, and thus embraced a portion of what to Englishmen was still a *terra incognita*; and there was much reason to believe that Russian Officers had already acquired a large amount of information regarding the regions to the south of their frontier line, and that they would not be unwilling to impart this information to a British Officer.

(3.) At St. Petersburg, I received every assistance from Lord Napier, the British Ambassador, by whom I was introduced to General Miliutine the Minister of War, M. Golovinne the Minister of Public Instruction, and Admiral Lütke the President of the the Russian Geographical Society. I readily obtained access to the Archives of the Geographical Society, which were replete with valuable publications and maps, many of which had not yet found their way to England. To obtain free access to the Topographical Department of the War

* See Pere du Halde's China, and more particularly the Geographical observations on the Map of Tibet, by Pere Regis.

Office was anticipated to be a more difficult matter, for in all parts of the world the time honored custom still prevailed of treating the documents in such offices as secret and confidential, and not to be shown to foreigners; but General Miliutine at once authorized my admission to the Topographical Office, and I have every reason to believe that I was shown all the maps it contained of the regions in which I was interested. In one respect I was disappointed; I found that the Russians had not carried their explorations to any thing like the distance beyond their frontier, that the British had done in India; though they were then holding the north-west portion of Kokan, around Tashkend, they had very little knowledge of the central and eastern portions of that important Khanat; the treaty by which they had obtained a grant of land for a factory in Kashgar was still a dead letter, only one Russian Officer having visited Kashgar, and he went there in disguise and was unable to take any observations for fixing it's position; and it appeared that such knowledge of Turkestan as was possessed by the Russians was derived, for the most part, from the same sources as our's,—namely from the maps of the French Jesuits, which were a century and a half old. But there were expectations that this state of ignorance would not last long; the Russian Government had appointed as Political Agent to the Native States in Turkestan an accomplished astronomer, M. Charles Struve, who was expected to determine the correct positions of all places of importance near the boundary line, and thus it was hoped that very valuable data for the rectification of the existing maps would be soon forthcoming.

(4.) I obtained the following maps;

1. Southern and Eastern Siberia including parts of Mongolia and Chinese Tartary, recently published by the Russian Geographical Society.

2. Central Asia between the parallels of 20° and 50° and meridians 40° to 90° East of Greenwhich, by the Topographical Department of the War office; 1863.

3. Western Siberia, and the countries between the parallels 42° to 62°, and meridians 62° to 85°, by the Topographical Department of the War Office; 1818.

4. A manuscript map of the Khanat of Kokan, based on information recently supplied by the Russian Consul at Guldja.

5. A catalogue of the latitudes, longitudes and heights of all positions of importance in Asiatic, Russia, Persia, Chinese, Tibet and Tartary which had been determined up to 1863 by triangulation or Astronomical observations.

6. Various publications of the Russian Geographical Society.

(5.) Returning to England I secured the assistance of Mr. Robert Michell in making translations of the various Russian documents I had received and in transliterating the names on the maps; and for some years afterwards, up to the time when Mr. Michell obtained an appointment in the India office, I was regularly supplied by him with translations of Russian publications furnishing new information on the Geography of Central Asia.

(6.) In 1866 my map of Central Asia was published; in it's compilation the whole of the regions to the north of 40° were taken from the Russian sources indicated in the preceeding paragraph; all to the south of 38° from British sources; for some portions of the intermediate belt of two degrees in latitude it was still necessary to depend on the maps of the French Jesuits which have already been mentioned, though additional details were furnished by recent itineraries. The position of Ilchi, in Khoten, having been lately determined by Mr. Johnson, in connection with the operations of the Trigonometrical Survey of India, furnished a point to which the details in the Jesuit's maps could be referred with accuracy,

so that there was reason to hope that the correct positions of the chief towns in Eastern Turkestan had been fairly approximated to.

(7.) Very shortly after the publication of this map, I received from M. Otto Struve, Director of the Poulkova Observatory, a list of nearly fifty positions near the southern borders of the Russian territories, which had been recently determined by his brother Charles, whom I have already mentioned as having been deputed for this purpose by the Russian Government.* The results shewed that the existing maps required a considerable amount of rectification, and strange to say to a much greater extent in latitude than in longitude. Thus the town of Chemkend, which had been hitherto supposed to be in latitude 42°43′ and longitude 69°40′ from Greenwich, was found to be in lat. 42°18′ and long. 69°36′; Tashkend required to be placed upwards of thirty miles further south and about twenty to the east, and generally a very considerable amount of southing was required for all the chief towns between Aulicata and Bokhara.

(8.) I then commenced the compilation of the map of "Turkestan, with the adjoining portions of the Russian and the British territories." It was constructed in four sheets which were published consecutively during the years 1867 and 1868. For the southern portions of this map, which indicate the regions immediately adjacent to the British Frontier, there were then no other materials available than those which had been used in the map of Central Asia, but I had obtained several Russian maps, in addition to the astronomical points, for the correction and amplification of the geography of the regions contiguous to the Russian Frontier. Of these the most accurate and valuable was Admiral Butakoff's map of the Sir-Daria (Jaxartes), and Severtsoff's Geological map of the country lying between the Sir-Daria and the River Chui. I also obtained copies of the sketch map of Northern Bokhara with the conterminous portion of Turkestan, which was prepared for Saturinoff's Journal of Struve's mission to Bokhara in 1865, the Chart of Routes in Kokan from Tashkend to Namangan and Margilan published by the Russian Geographical Society in 1867, and a map of Turkestan published at St. Petersburg by A. Ilyin.

(9.) Geographical science, when it is not advanced by sound and systematic surveys but is dependent on information acquired from the itineraries of travellers and from cross questioning the inhabitants of a *terra incognita*, has to make it's way by zig-zags of approach, often over-shooting the mark to which it is directed, sometimes perhaps going wrong altogether, but yet always endeavoring to reach it's goal by successive approximations. This is pre-eminently the case as regards the geography of the portions of Central Asia which respectively lie beyond the boundaries of the Russian and the British territories, and more so as regards the former than the latter, for accurate and continuous surveys on a trigonometrical basis have now been carried up to the British frontier, throughout it's entire length, whereas on their side the Russians have not yet had time to execute such surveys, and their maps are mostly compiled from reconnoisances and itineraries, of varying orders of merit, which are put together on the basis of a few points whose positions have been determined astronomically. It is evident therefore that until all such data have been superceded by the results of a rigorous and systematic survey, Central Asian geography can only be considered as a preliminary approximation, which is liable to be largely corrected in future.

* While engaged in these operations M. Struve was taken prisoner, and held in captivity in Bokhara for several months, which probably was one of the causes of the subsequent extension of the Russian boundary in that direction.

(10.) Sir Roderick Murchison, in his address to the Royal Geographical Society at the anniversary meeting in May 1869, said of the map of Turkestan that "this work of Colonel Walker's does not enter into great topographical detail, but it is invaluable as a combined view of the sound results obtained up to the latest date, and marks a step in our chartography of that region such as has not been made for nearly thirty years." But such has been the progress of geographical exploration, on the part of the British as well as the Russians, since the publication of that map that it is now found to need numerous corrections and additions, and to be altogether insufficient for present requirements. It moreover contains a grave error in an attempted rectification of the course of the Zarafshan river; in the preceding map of Central Asia that river was shown as rising in the hills south of the Khanat of Kokan at a distance of about 4½° to the east of Samarcand, and trending westwards, between two parallel ranges of mountains, until it reached the vicinity of Samarcand; but in Saturinoff's map (see para. 8) the source of the river is placed in the Lake Iskunder at a distance of barely a degree to the east of Samarcand, and the two ranges to the south of Kokan give place to a single range; the propriety of this rendering was supported by a recent determination of the position of the town of Kokan, placing it more than a degree to the south of the position which had been previously accepted. These supposed rectifications were introduced into the Turkestan map, but they have now been found to be erroneous; the river Zarafshan was afterwards explored to it's source by M. Fedchenko, and the original rendering of the river is now known to be much more accurate than that by which it was for a time supplanted.

(11.) To correct this error, and to utilize the results of recent surveys and explorations, a new edition of the map of Turkestan has been prepared. It has been extended west-wards to embrace the Caspian sea, which was not shown in the first edition. In it's compilation the following recent maps and documents have been used in order to correct and add to the details in the first edition.

From British and Asiatic Sources.

1. Trans Himalayan Explorations under the superintendence of Major Montgomerie; *viz.*, the Pundit's Explorations of the Upper Basins of the Indus, Sutlej and Brahmaputra rivers, 1865-67; the Mirza's Route from Badakshan across the Pamir steppe to Kashgar, 1868-69; and the Havildar's route from the Panjab to Badakshan, through Swat, Dir, and Chitral, 1870.

2. Two skeleton maps (without hills) by Major Montgomerie, called "Trans Frontier Maps, compiled from Route Surveys and Astronomical Observations made by British and Asiatic explorers from the side of India"; 1872-73.

3. Captain Carter's chart of trigonometrically fixed points west of the Indus, between the British Frontier and the water-shed of the Hindu Kush; 1869-70.

4. Map of the Sistan boundary by Major Lovett; 1872.

5. Report of General Sir Frederic Goldsmid on the Sistan boundary; 1872.

6. Route from Bam to Sistan and thence to Meshed by General Sir F. Goldsmid, 1872.

7. Route from Shiraz to Bam, Major Lovett; 1872.

8. Route from Teheran to Bushire, by Major St. John; 1871.

9. Map of Affghanistan compiled in the Quarter Master General's Office, Simla, 1871.

10. Colonel Johnstone's Sketch Map of the North Western Frontier, from Fort Abazai to Fort Mackeson, 1869-70.

11. The communications of Messrs. Hayward and Shaw to the Royal Geographical Society, published in the Society's volumes for 1870 and 1871.

12. Map of Central Asia, by John Arrowsmith, 1872.

13. Map of Eastern Turkestan, to illustrate Mr. Forsyth's Journeys, 1871.

14. Travels in Central Asia by Mir Izzat-Ullah, in the years 1812-13, published 1872.

15. Journey from Peshawar to Kashgar &c. by Faiz Buksh, 1870.

16. Route from Kokan to Peshawur, *viâ* Karategin, by Shazada Sultan Muhamad of Kokan.

17. Map of Independent Territory west of Indus and south of Oxus, compiled by a Moulvie in the service of Captain Ommaney, Deputy Commissioner of Hazara.

18. Reports of the meetings of the Royal Geographical Society, published in "Ocean Highways, the Geographical Record" by Clements Markham, C.B., 1872-73.

19. Colonel Yule's Introduction to the second edition of Wood's Oxus, 1872.

20. Map of Central Asia, compiled at Topographical Department of War office, and corrected to March 1873.

From Russian Sources.

21. Additional astronomical determinations of position, by M. C. Struve.

22. Map of the Khanat of Kokan, by M. C. Struve, scale 20 versts=1 inch; 1871.

23. Map of Turkestan by Captain Liusilin and Colonel Narbut, of the Russian Topographical Department; 1871.

24. Map to illustrate Baron Osten Sacken's Route from Vernoe to neighbourhood of Kashgar; 1868.

25. Topographical sketch of the Zarafshan valley by M. Fedchenko; in the Journal of the Royal Geographical society for 1870.

26. The principality of Karategin, by General Abramof, Chief of the Zarafshan district; in the Journal of the Royal Geographical Society for 1871.

27. M. Fedchenko's accounts of his expedition up the Zarafshan valley in 1870, and his travels through the Khanat of Kokan in 1871, as translated in "Ocean Highways" from the proceedings of the Imperial Russian Geographical Society for October 1872, and published in the proceedings of the Berlin Geographical Society.

28. Chart of Central Asia, by the Russian Topographical Department; 1863; new edition corrected up to end of 1872.

(12.) I very much regret that I am unable to add to the above list M. Fedchenko's new map of Kokan, which I have made several efforts to obtain but hitherto without success. It should be very valuable, for M. Fedchenko has succeeded in penetrating into Karategin, and reaching the neighborhood of the celebrated Tirak pass between Kokan and Kashgar, and he has thus had great opportunities of correcting erroneous geography; he is stated to believe that he has cleared up "many points which are yet problematical," and also to be of opinion that "there remains now but very little to determine on one of the great geographical mysteries of the world." I am informed that he is preparing an elaborate account of

his explorations and solutions of geographical mysteries, and that the publication of his map will be postponed until his book is ready.

(13.) It is desirable that I should here point out the geographical alterations and additions which have been made in the construction of the second edition of the map of Turkestan now in publication, giving my reasons for them wherever necessary.

1. The map has been enlarged so as to embrace the region between the meridians of 46° and 58° East of Greenwich, to which much interest attaches at the present time.

2. The error in the course of the Zarafshan River, noticed in para. 10, has been rectified.

3. The route from Badakshan to Kokan, *viâ* Kolab and Karategin, is stated by M. Fedchenko to have been originally traced inaccurately, because of the errors in the position in Kokan. It is now made to cross the great range of mountains to the south of Kokan nearly a degree to the east of the position formerly accepted, at the Karategin pass of M. Struve's map. Much additional information regarding this route and the valley of the Surkhab river has been obtained from the Itinerary of Shazada Sultan Muhamad of Kokan, whose route from Kokan to Lungur Eshan goes through several places on Abdul Majid's route; from Lungur Eshan to Abigurm the Shazada's route keeps near the river Surkhab, passing through several places noticed in General Abramof's account of Karategin, while Abdul Majid appears to have taken a more direct route to Kolab, keeping away from the river and crossing several spurs of the Darwaz hills. From Abigurm the Shazada proceeded *viâ* Baljawan, which is believed to be near the Surkhab River, to Kolab, where his route joins that of Abdul Mejid.

4. In the delineation of the Khanat of Kokan M. Struve's map has been exactly followed up to the meridian of the Karategin pass, 72° 20′; but from that point eastwards, I have thought it desirable to make some considerable deviations. M. Struve places the Tirak pass* very much closer to Kashgar, than is reconcileable with the information given in the itineraries of Muhamad Amin, and Mir Izzat-ullah; he makes the distance from Kashgar equal to 2·7 tenths of the distance between Kashgar and Kokan, while they agree very closely in making it 4·4 tenths of that distance, the difference being equivalent to about 1¼ of a degree in longitude. M. Struve's geography of this region is probably based on native information which is no better than that furnished by the itineraries of Muhamad Amin and Izzat-ullah; I have adopted a mean between his value and their's, and assumed the Tirak pass to be at 3·6 tenths of the distance from Kashgar that Kashgar is from Kokan. I thus place the pass in long. 74° 15′, instead of 74° 55′ as by M. Struve, but our latitudes are the same, *viz.*, 39° 42′. The position adopted for the first edition of my map of Turkestan was 39° 18′ by 72° 48′, nearly half a degree to the south and a degree and a half to the west of the position now adopted. I trust that the uncertainty about the position of this pass—which is an obligatory point of the highest importance—has been cleared up by the labors of M. Fedchenko. He is reported to have said, in a preliminary account of his travels, that the pass should be shifted 80 versts (53 miles) to the west and 30 versts (20 miles) to the north "of the position hitherto given on the maps"; but as it is not stated on *what* maps, the information is indefinite; it tends however to confirm the propriety of my deviation from M. Struve. In the new edition of the Russian Chart of Central

* Otherwise spelt Terek, Turak, Tarcek by various authorities, and Teezuk by the translator of Mir Izzat-Ullah's travels.

Asia (28 of para. 12) the pass is placed in lat. 40° 8′ by long. 73° 30′. The geographical zigzags of approach to this pass would seem to have gone very wide of the mark hitherto.

5. I have placed the town of Kashgar in lat. 39° 29′, long. 76° 12′, and that of Yarkand in lat. 38° 20′, long. 77° 30, the positions determined by Major Montgomerie from the route surveys of his native explorers, and upheld by him in his recent Trans Frontier skeleton maps.

6. The original delineation of the district of Tashkurgan has of course been superceded by the Mirza's survey of the route from Badakshan across the Pamir Steppe to Kashgar. A comparison of the Mirza's route with those of Muhamad Amin and the map constructed by Captain Lumsden from Muhamad Amin's itineraries, shows that there is much probability that the Sussogh Kul of Abdul Majid's itinerary is in reality Wood's Sirikul or Lake Victoria, though it has hitherto been placed about 45 miles to the north-west of that lake;* Muhamad Amin gives a lake—merely called Ab-i-Pamir Kalán—in a similar position relatively to another lake which he calls Sirikul and which was therefore supposed to be Wood's lake. But it is now quite clear that this Sirikul is identical with the Mirza's Barkut Yassin Lake, which lies about 40 miles to the south-east of Wood's Sirikul; as the word Sirikul literally means a lake on a summit, and there are many lakes so situated in this region, the name is not sufficient to ensure identification. The merging of the Sussogh Kul into Wood's lake has a very important bearing on the geography of the Pamir Steppe; it throws the starting point of our best itineraries across this region to the Tirak pass considerably to the east, and as the position of the pass has been carried still further to the east, I have found it necessary to move Lake Karakul about 1½° in the same direction.

7. The region lying between the eastern edge of the Pamir Steppe, the valley of the Surkhab River and the River Panja of Wakhan—the southern branch of the Oxus—covers an area of about 40,000 square miles which is still a *Terra Incognita* to Englishmen. It is probably a highly elevated plateau, which culminates in the Bam-i-Dúniah, the highland of the Pamir on which Wood's lake is situated. To the south-west it is bounded by a prolongation of the spur from the Hindu Kush range northwards passing between Ishkashm and the upper sources of the Kokcha river, which must take the form of a highly elevated scarp on it's western face, which towers over the valley of the Kokcha, while it's eastern face has a comparatively slight command over the elevated plateaux of Wakhan and Shagnan. It is not improbable that this scarp is prolonged northwards and then north-eastwards into Karategin, and that it's crest is the watershed between the *Terra Incognita* and the valley of the Surkhab River. The whole of the drainage of this region appears to join the Panja River on the east side of this range, the united streams forming the Oxus, which, after bursting through it's mountain barriers, and descending from a probable elevation of 7,000 feet to one of 700, enters an alluvial plain as a noble stream having a breadth, opposite Sarchasmah, of upwards of a mile in winter and some six miles in summer during the melting of the snows. The Shazada Sultan Muhamad is my authority for the breadth of the Oxus at this point, and though he may have exaggerated it, yet the fact that neither his itinerary nor that of Abdul Majid mentions the passage of any river on the routes between Lungur Eshan and the Oxus, shows that the existence of large rivers flowing westwards through the *Terra Incognita* into the Surkhab is highly improbable, and strengthens the pro-

* Major Montgomerie I find has adopted this view, and is supported in it—though with some hesitation—by Colonel Yule.

bability of these rivers joining the Oxus above the point of it's entry into the lowlands.

8. A recent writer in the Times—see the Mail of 9th April, 1873—in reviewing Colonel Yule's edition of Wood's Oxus, draws attention to "the curious forgeries produced by dearth of information concerning Central Asia." He says of these forgeries that "they have been adopted in Colonel Walker's map, and transferred from it to others, even that of the Topographical Department; thus the course of the Oxus in it's northern bend, and the districts of Shagnan, Roshan, and even Wakhan, are tortured out of shape and place." This would be very sad and pitiful if it were only true. But as a matter of fact Shagnan and Roshan do not appear in either of the maps which I have published hitherto, though they will be found in the new edition of Turkestan. On the other hand Wakhan has always been shown without having undergone a process of torturing, for it was placed exactly as Wood—the only Englishman who has ever been there—placed it, and Wood's rendering is accepted and followed by Colonel Yule. Shagnan and Roshan fall within the *Terra Incognata*, as will be at once evident from an examination of the attempts to give them shapes and places which have been made by the geographers who are believed to have known or to know most about them. For example, Shagnan—which in deference to Colonel Yule will hereafter be spelt Shighnan—is shown in Wood's map as the portion of the valley of the Panja river *below* Wakhan, having the direction S. S. E., to N. N. W., with a length of about 60 miles. In Colonel Yule's it lies in great part in a lateral valley, called the Shak-dara, about 30 miles to the north of and nearly parallel to, the course of the Panja River through Wakhan; it has the direction N. E. to S. W., with a length of 110 miles and an average breadth of 30 miles; beyond it (northwards) a third parallel valley is shown, which Colonel Yule thinks may be the *Vallis Commendarum*. Colonel Yule and Lieutenant Wood agree in locating Shighnan wholly between the 37th and 38th parallels of latitude; but according to M. Fedchenko *(see Ocean Highways for December* 1872, *page* 289*)* the Shighnan territories must reach to a distance of at least a degree further north, for he says that the valley of the Muk-su separates them from the Alai plateau; he believes that they "lie to the east of Darwaz, extending probably two degrees along the meridian", or in other words that they embrace an area which is far greater than has hitherto been imagined by the best English authorities on the subject. The matter is one of no small importance, if Colonel Yule is correct in his statement that Shighnan acknowledges the supremacy of Badakshan.

9. In the first edition of the map of Turkestan the District of Darwaz is placed wholly to the north or on the right bank of the Oxus, and it is retained there in the second edition, because I have failed to discover any satisfactory authority for extending it to embrace a portion of the region on the left bank of the Oxus; the fact however that this has been done in Colonel Yule's map and Lieutenant Wood's also is, I must admit, a strong argument against the validity of my own conclusions, and the accuracy of my information.

10. Colonel Yule observes in his Essay that I have "more than once expressed an opinion that there is no well-defined range where the Hindu Kush is represented on our maps", and he adds that he thinks these words are far too strong. They appear to be quoted from the printed report of a discussion at the meeting of the Royal Geographical Society on the 24th April 1871; I cannot find them anywhere else. The words taken by themselves may well

be considered to be too strong, but Colonel Yule has overlooked the circumstance that they were spoken with reference to Mr. Shaw's discovery of places in the Karakoram range where there is a break of continuity in the range, and the line of watershed is almost lost, and can only be traced with difficulty, on the high table lands into which the range disappears for a while to reappear further on beyond them. Speaking of the Hindu Kush range I expressed my belief that a counterpart to the break of continuity in the Karakoram would be met with there, and I think there can be very little doubt of this. At a subsequent meeting of the Royal Geographical Society, on the 13th May 1872, I said of the portion of the Hindu Kush range which lies to the north of the valley of Chitral that, as our geographical knowledge improved, "we should probably find that the system of mountain chains, as re-" presented in our maps, would require great alteration, that the dark range now " representing the watershed would be found much lower than is now supposed, " and that the higher ranges were to the south of it." Colonel Yule must I think agree with me, for in his recently published map the watershed has, for the first time, been greatly subordinated, and nearly disappears altogether, in the vicinity of the passes leading out of the upper Chitral valley into the Sarhad Wakhán and Pamir, where hitherto it has invariably been shown as a great range towering over all others. The depression of the main line of watershed as compared with the great mountain ranges is a well known feature in Himalayan geography, the counterpart of which doubtless obtains in the Hindu Kush range also. And I find that Major Montgomerie has recently arrived at the conclusion that the watershed line between the Hindu Kush and the Karakoram ranges lies considerably behind (to the north of) the line of high peaks which he fixed trigonometrically several years ago, and which have ever since been accepted as the actual line of watershed, whereas they are now ascertained to belong to off-shooting higher ranges.

11. Numerous additions and rectifications of the geography of the countries between the watershed of the Hindu Kush and the British Frontier line have been made on the basis of Captain Carter's triangulation, by which upwards of a hundred hill peaks have been newly fixed in this interesting region. The Havildar's expedition through Swat, Dir and Chitral to Badakshan has not only furnished very valuable details in itself, but has been otherwise serviceable in enabling Major Montgomerie to utilise the results of an exploration through the Swat valley to the sources of the Swat river and thence westwards into the Panjkora valley, which was made some years ago by one of his explorers, who was unfortunately murdered in Swat; his papers were recovered, but they were wanting in some particulars which were necessary for their verification, and this missing link has been furnished by the Havildar's survey, which fixed the closing point of the previous survey.

12. The geography of Kaffiristan is still dependent on the valuable rough sketch which was compiled by Lieutenant (now Major General) Peter Lumsden in 1858, from information supplied to him by Kaffirs; this sketch was published in Major H. B. Lumsden's account of the Mission to Kandahar, and it's general accuracy has been corroborated by Captain Carter's recent operations, which have fixed a large number of hill peaks in Kaffiristan and proved that the disposition of the mountain ranges is very closely in accordance with what is shown in Lieutenant Lumsden's sketch.

13. Colonel Johnstone has ascertained that there is a very remarkable bend in the course of the Kabul river through the range of hills which separates the

valleys of Jellalabad and Peshawur, and his delineation thereof, in his map of the North Western Frontier from Fort Abazai to Fort Mackeson, is corroborated by Captain Carter's operations. On the authority of the map of Afghanistan which was constructed by Colonel Garden, late Quarter-Master-General of the Army, from the route surveys of the officers of his Department, the river is shown on all modern maps as having a nearly straight course through those hills; Colonel Garden's surveyors however worked through the Khyber pass, from Jamrud to the vicinity of Lalpura, and did not traverse the course of the river, so they could only shew it approximately, whereas Colonel Johnstone has succeeded in surveying it's course westwards beyond the Peshawur valley up to the bend in question. On the other hand beyond the bend his map is based on native information, and it brings Lalpura several miles to the east of the position which is given by Colonel Garden, most probably from actual survey. Colonel Johnstone's rendering of Lalpura is followed in the map of Afghanistan compiled in the Quarter-Master-General's office at Simla in 1871, but I think on insufficient grounds; I have therefore retained Lalpura in the position assigned to it by Colonel Garden. As regards the great bend in the Kabul river, I may observe that it is not a new discovery but the re-discovery of a fact which was well known to Lieut. Wood, who states at the end of his book that, on leaving Afghanistan, he and Dr. Lord embarked on the Kabul river at Jellalabad "on rafts of inflated skins, and dropped down with the stream to Peshawur;" so remarkable a feature could not have escaped the attention of so accurate a geographer, and accordingly it will be found duly portrayed in the map accompanying his book.*

14. A route survey, the details of which have not yet been published, has been carried by Major Montgomerie's Havildar from Kabul to Bokhara; it slightly alters the positions of Balkh and Karshi, which may now be considered to be known very approximately, and it adds new details which, though somewhat meagre, are not without interest. Unfortunately the Havildar did not pass sufficiently near Shahr-i-Sabz to be able to determine whether M. Khanikoff is correct in placing Yakobak some 30 miles to the east of that town, or M. Fedchenko in removing it to about half that distance to the south. M. Fedchenko's rendering, being the latest, has been adopted.

15. The valuable surveys of Major's Lovett and St. John in Persia, and along a considerable portion of the line of boundary between Persia and Afghanistan, have been carefully incorporated into the new map, and the details of the countries on either side of the lines of survey have been re-adjusted so as to harmonize as closely as possible with the rectifications now furnished.

16. The surveys of the Pundits near the sources of the Indus and the Sutlej Rivers have been incorporated into the new map, and also a route from Rudok to Keria and Khotan, passing to the east of the Kuen-lun range, over the Aksai Chin or White Desert; and a few corrections and additions have been made—on the authority of Messrs. Forsyth, Shaw and Hayward,—to Mr. Johnson's delineation of the regions to the north of the Karakoram Range and the Changchenmo valley, which had been previously adopted.

* It is much to be regretted that this map was constructed on so small a scale; this was evidently done to enable it to embrace the course of the Indus from Attock to Karachi; but at the present time the chief interest of the book and map centers in the regions north of the parallel of 34°, and if the original surveys are still forthcoming their publication on a large scale would be a great boon to geographers; had this been done originally, the mistake in the delineation of the Kabul River would probably not have been made. As regards the position of Lalpura, I have heard from Colonel Johnstone, since the above was in type, that he has discovered an error in the construction of his map which accounts for his disagreement with Colonel Garden.

(14.) As regards boundaries, they are the *bête noire* of a geographer, more particularly when they are shifting and uncertain; but they increase the interest with which a map is regarded, and as approximations are better than nothing at all, some of the principal boundary lines are shown approximately in the new map.

1. For the Russian Boundary I have adopted the line given in the latest of the Russian maps already cited, on which it is shown; the last map of all however does not indicate any portion of it to the west of a meridian line passing nearly midway between Bokhara and Samarcand.

2. The northern boundary of Persia has been carried along the entire course of the Atrek river from the point where the river enters the Caspian Sea to the point where it's principal source is supposed to originate; thence it is drawn eastwards for about one hundred miles and then diverted to the south-east, in a nearly straight line, to the point where the Heri-rud crosses the parallel of 36°; here it is made to meet the northern boundary of Afghanistan. The boundary between Persia and Afghanistan is thence drawn as following the course of the Heri-rud river south-wards to a little above Shahesk (lat. 34° 40′) where it leaves the river and is carried due south to the parallel of 33°, and then is bent slightly west-wards to cross the road between Lash-Jowain and Birjand at the wells of Chah-i-Sagak; thence it is carried south-east and south-wards to the Sistan District, through which it follows the line demarcated by General Sir F. Goldsmid, which is generally south-east down to the fort of Nadali—lat. 31°, long. 62°—and south-west onwards to a point, in lat. 30° long. 61¼°, where it is supposed to meet the boundary of Beluchistan. Thence the boundary line between Persia and Beluchistan is carried in a south-easterly direction towards a hypothetical point in the valley of the Mashkid river, in lat 27¼° long 63¼°, which is beyond the limits of the map.

3. The northern boundary of Afghanistan is drawn as trending E.N.E. in a nearly straight line, from the point where the Heri-rud River crosses the parallel of 36°, to Khoja Saleh on the River Oxus. It is carried thence up the course of the Oxus and it's principal source—the Panja River—to Wood's Lake Victoria, in conformity with the line of boundary which has been approved of by the British and the Russian Governments.

4. A very considerable portion of Eastern Turkestan, which in the first edition of the map was shown as Chinese Territory, is now subject to the Atalik Ghazi, whose territorial acquisitions appear to be daily increasing; this is more particularly the case eastwards towards China, where they have extended beyond the limits of the map; even westwards there has been some extension, according to M. Fedchenko, who says that "a large portion of the Kokan Khanats must be cut off and made over to the territories of Yakúb Beg". I have not attempted to assign any boundaries to the countries under the sway of this acquisitive potentate.

5. The northern boundary of the territories of the Maharajah of Kashmir has—on the authority of Mr. Forsyth—been brought back a considerable distance from the line indicated in the first edition of the map. It is now carried along the northern edge of the Chang-chenmo valley and over the ridges of the Karakoram and Mustagh ranges, up to a point on the meridian of 75°, whence it is turned south-west to meet the meridian of 74°, and is then carried—as formerly—along the ridge of the range on the southern side of the Gilgit Valley down to the River Indus. The highly elevated but uninhabited region of table lands between the Karakoram and the Kuen-lun ranges, was believed—on information derived from Mr. Johnson—to appertain to the Maharajah of Kashmir, at the time when

the first edition of the map was published; it would however appear to be a sort of no-man's-land at the present time. Yassin and the valleys of the upper sources of the river of Gilgit are at present subject, if at all, to Chitral rather than to Kashmir.

(15.) I cannot close these remarks without expressing my obligations to M. Otto Struve, the Director of the Imperial Observatory at Poulkova, for favoring me with the results of his brother's astronomical determinations from time to time, immediately after they were deduced; to the Baron Osten Sacken—late Secretary to the Imperial Geographical Society of Russia—to whom I am indebted for many valuable communications; and to Captain Lütke, the present Secretary, who promptly responded to my application for geographical information, by sending me one of the few photographed copies which had been made of M. C. Struve's valuable map of Kokan. To Mr. Clements Markham, C.B., of the India Office, and to Colonel Thuillier C.S.I. Surveyor General of India, I am indebted for early copies of all maps giving new information of the geography of Central Asia, which have been published in England or communicated to the India office. In the compilation of my first maps I was largely indebted to the late Mr. William Scott, who for many years was Chief Draftsman in the office of the Trigonometrical Survey at Dehra Dún; the compilation of the present map has been, in a great measure, my own work, but in executing it I have been much assisted by my present Chief Draftsman, Mr. George Atkinson.

Dehra Dun,
4th June 1873.

J. T. WALKER, COLONEL, R.E.,
Supdt. Great Trigonometrical Survey of India.

Postscript, December 11th, 1873.—Since the preceding notes were published, I have received a letter from Mr. Forsyth in which he demurs to being named as my authority for the alteration in the northern boundary of the territories of the Maharajah of Kashmir which brings it a considerable distance within the line indicated on the first edition of my map of Turkestan. Further correspondence has elicited the fact that Mr. Forsyth was not aware that I had simply followed the delineation adopted in his own map of Eastern Turkestan (*see clause* 13 *of art.* 11) which was compiled in 1871 under his superintendence—in the Surveyor General's Office at Calcutta—to illustrate the report of his first journey to Yarkand; there the new boundary line is shown, but on the authority—as it now appears—of a map constructed by the late Mr. Hayward, which Mr. Forsyth had furnished to be used in the compilation of his own map, unfortunately without stating that he objected to the alteration. Under the circumstances it is to be regretted that any alteration was made, and that Mr. Forsyth should have been brought forward as the authority for a line of boundary to which he objects most strenously, in opposition to the views held by Mr. Hayward and other persons.

J. T. W.

Note on the alterations and additions in the Re-prints of Sheets No. 1 *and* 3 *of the 2nd edition of the Map of Turkestan, which were published in the Office of the Great Trigonometrical Survey of India in November* 1873.

It has been thought desirable to incorporate into Sheets No. 1 and 3 of the Turkestan map (2nd edition) the information which was appended to them in a separate "Addendum" when they were published—in April last—and which was not received in this office until after they had been passed through the press.

(2.) The opportunity has been taken to make some alterations in the delineation of the boundaries of Persia in accordance with information received since the issue of the map. It must be understood however that any delineation of this and of other boundary lines which have not been determined and surveyed can only be considered as an approximation, to serve as a *pis aller* until conclusive results are obtained from actual survey.

(3.) The hills in the basin of the Atrek River and its affluents have been taken from the latest edition of the London War Office map of Khiva; further details of the Sir-daria District have also been added from recent maps of the Russian Topographical Department.

(4.) Major Lovet, R.E., who was employed on the Sistan Boundary Commission, has furnished a list of a few errata in the routes from Shiraz to Bam and from Nasirabad to Birjand. In making the requiste corrections a serious error was discovered in the positions of Birjand and Káin and all places on the road between them; the data by which they had been laid down—on sheet No. 3—were the latitudes and longitudes which are given in Major Evan Smith's Tabular Itinerary of the march of the Sistan mission from Bunjar to Mashad; but the longitudes there given of Birjand, Káin and all intermediate places are found to be half a degree too great or too much to the east, by comparison with the details of the distances and bearings which are given in the itinerary, and with Major Lovett's map of the route. These errors have been corrected in the Re-print.

J. T. WALKER, COLONEL, R.E.,
Supdt. Great Trigonometrical Survey of India.

DEHRA DOON,
5th January 1874.

Extract from the Narrative Report—dated 15th July 1873—of W. C. ROSSENRODE, ESQ., Deputy Superintendent 3rd Grade, in charge Southern Section Bilaspur Series.

(3.) On receipt of my Narrative Report and rough chart of last season, Major Montgomerie, R.E., remarked "In brief I cannot accept principal triangulation devoid of secondary work and on this point I must call your attention to letter No. $\frac{22}{991}$, dated 21st October 1868, from the Superintendent G. T. Survey."

(4.) Mr. Bell rejoined the party on the 26th October last, and before commencing field operations I arranged the following programme for accomplishing the utmost quantity of secondary work, in compliance with your orders to the late Mr. Shelverton above cited. My shortcomings the previous season were attributable, not to inattention to your orders, but to a paucity of assistants, owing to which, I could not execute the secondary work you desired. For the same reason another important duty could not be attended to; the construction of rectangular pillars, and the handing over of the stations completed to the local authorities. I endeavoured during the late field season to accomplish both, by detaching all the three assistants to carry out your wishes, retaining only a native writer to assist me in the observatory and in office duties,

MR. BEVERLEY — To determine the positions of the towns of Jaipur and Jagdalpur, the residences of the Rájas of Jaipur and Bastar; to lay down all towns and villages within the principal triangulation of the first polygon and a half, and to fix the position of the civil station of Korápút.

MR. BELL — Was assigned the remaining polygon and a half, and he was instructed to determine the positions of all important places.

MR. WRIXON — To construct rectangular pillars, and to place the completed stations under the protection of the local authorities. He was also directed to execute as much secondary work as he possibly could within the principal triangulation completed the previous season.

(5.) I had much difficulty in entertaining men and cattle to proceed with me on field duty. The inhabitants of Wálter, Vizagapatam and Vizianagaram, dread the Jaipur and Bastar jungles, owing to their unhealthiness. The men who had hired their bullocks the previous season, for conveying the baggage of the party, demanded extra hire. Fresh men were engaged by paying eight annas per bullock in excess of last season's hire; their agreements were taken on stamped paper, and by advancing them a month's hire for each bullock, I secured the full complement of baggage cattle for the whole party. The bearers who had carried the great theodolite would on no account take service, owing to 5 deaths having occurred the previous season after their return to recess quarters. I was in a measure prepared for this, and arranged for bearers from Hazáribágh who had served with me in Assám, Cachar, Tipperah, Chittagong and Arracan.

(6.) All preliminary arrangements having been made the lampmen left Wálter on the 14th November to occupy their respective stations. The main camp followed on the 20th and reached Sálúr, a large town, on the 28th by stages. Here heavy rain fell, and continued day and night without intermission until the afternoon of the 1st December.

(7.) I apprehended much sickness in camp owing to the continuous wet weather; the men were without proper food, and had to sleep on the damp ground; the straw was wet, and nothing dry could be obtained. A large quantity of wood was purchased, fires were made for the men to dry their clothes, and to keep them warm. My fears however were groundless; with the usual precaution of administering quinine to the men, and removing them at once, when the rain ceased, to the high hills of the Korápút range, the health of the party remained good.

(9.) I reached Burdwar, my first station, where I closed operations the previous season, on the 10th December, completed work on the 12th and marched next day to the secondary station of Amá. From thence I proceeded to Sirsi H.S. where I arrived on the 19th: that very night an epidemic broke out among the pack bullocks, 4 of which died on the 20th, 2 more casualties occurred the next day, and I lost five others before I reached Motigáon H.S. on the 24th December. Having lost 11 baggage bullocks I separated those which were stricken from those which had not taken the disease. The former were sent by easy stages to the station in advance where I intended observing an azimuth. This arrangement saved the cattle, but sickness broke out in camp; the Hospital Assistant, the Observatory Recorder, the Jamadár and 10 other men were prostrated with fever. I removed the camp from the foot of the hill in the forest to an open elevated spot near the village of Motigáon, three miles distant from the station; and after completing my observations, I marched to Karia H.S., taking the sick men with me to the station, and locating the whole camp on the summit of the hill. I lost one man on the 1st January 1873 and the others gradually recovered.

(10.) On completing my observations at Motigáon, H.S., I wrote to Mr. Beverley to join me at Karia H.S.: I had only a native recorder and he was prostrated with fever. Mr. Beverley was of very great assistance, for he not only recorded, but aided me in reading the microscopes. Karia was the centre of a hexagon and the azimuth observations were taken here, and with Mr. Beverley's assistance I completed my work rapidly. I am very much indebted to him for aiding me, and taking part in the observations. The 8 day's halt at Karia materially assisted in re-establishing the health of the camp. Fresh bullocks were purchased to replace the 11 which succumbed to the cattle plague, and being set up I made a fresh start and proceeded to Lambidongri H.S. Mr. Beverley resumed his secondary triangulation.

(11.) Lambidongri is situated on the highest point of an extensive plateau thickly wooded. The signal party who had preceded me made a good clearance for the camp: on my arrival I had many more trees felled, the grass and under growth was cut and removed, fires were lighted round the encampment after the night observations and were tended, fed and kept burning till the morning; every precaution was taken to ensure the health of the party, but during the three days I was detained there 16 fresh cases of fever occurred.

(12.) The remainder of the season the camp was never free from sickness; the Hospital Assistant suffered very much. He was a hale, hearty, active man when he left for the field; he returned a mere skeleton, devoid of energy. The Jamadár after lingering for upwards of two months died on the 4th March at Jerar village at the foot of Deodongri H.S.

(13.) It was impossible to move about with so many sick and feeble men, I therefore established depôts for them, selecting the most open, and healthy localities, and removing them as I advanced with the work. It may not be out of place to mention that at one time I had 36 men in hospital; berkandazes, kalasies, bearers and camp followers.

(14.) The final operations made good progress notwithstanding the crippled state of the establishment. The stand of the theodolite and telescope were carried by coolies, and coolies did mostly all the work, under the directions of the few effective men in camp: all the principal men including the Tindal were ill, I was myself suffering from fever. To be able to continue my duties I had recourse to large doses of quinine daily, which brought on partial deafness. I may here remark that not a single man escaped the fever of the country, even the cooks who are generally the most healthy, owing to their constant proximity to the purifying influence of fire, suffered repeatedly this season. The fever however was not of a virulent type; although it spared no one, and could not be radically driven out of the system, few casualties occurred.

(16.) I closed final operations at Attanga my last station on the 10th March, thus completing the southern section of the Biláspur Meridional Series exactly in three months. Final angles were taken at 16 principal stations, and one secondary station. A large quantity of secondary work was accomplished during the above period.

(18.) The country through which the operations, both principal and secondary, were carried on, varied in height from 5,000 to 2,000 feet above sea level. Ranges of hills were crossed, elevated plateaux traversed, every description of ground was met with, all of which was densely wooded; some portions were very difficult with scarcely a village; between the stages, other portions were cultivated, and had villages 3 and 4 miles apart. Colonel Saxton, Deputy Superintendent in charge No. 3 Topographical Survey, Central Provinces and Vizagapatam Agency, whose experience extends over many consecutive seasons, and who is quite conversant with the country and its people, remarks in one of his reports "In the physical features of the country there is little more to notice, all being hills and jungle, waste and desolation, with the scantiest population sunk in ignorance and vice."

(20.) Wild animals are numerous. Tigers are very destructive, and frequent desertions of entire villages occur annually from the ravages of these animals. At Karia H. S. one of my pack bullocks was carried off in the afternoon, and all the endeavours of the keepers and villagers to rescue the animal alive, proved ineffectual; the tiger standing over its prostrate victim deliberately satisfied himself with its blood and then retired into the jungle. Mr. Beverley who joined me at this station lost a bullock the same night. The cattle were removed the next morning to a safer locality after this second seizure and no more losses were sustained. At There H. S. one of my goats was carried away by a leopard during the day close to camp, the men were about at the time and rescued her; that very night my best milchgoat was taken and no trace of her could be found. Wild buffaloes are numerous, and very troublesome when they are met with on the line of march. A solitary bull having possesion of the path kept a few men of my camp at bay for some time until the elephant came up with the rear baggage, he decamped on seeing the elephant approach and left the path free.

(21.) There is no regular commerce in the country through which the triangulation was carried on this season, for want of roads. The export of grain is very large, and the Banjáras convey it on pack bullocks to the towns where there is a demand for it. In the Jaipur and Bastar Rája's territories, the revenue is paid partly in money and partly in grain, which latter is collected separately, each kind in its own granary, and the Banjáras purchase it and convey it to the profitable marts at Párvatipuram and Vizianagaram; from these two places it is carted to

Vizagapatam. Numerous bands of Banjáras resort to the above depôts, large quantities being readily obtained from the respective Rája's officials. The Banjáras are an interesting people and an account of them would not be amiss. I have met them frequently in the above states, and on the line of march on the high road, I have met their interminable string of bullocks. The tinkling of innumerable bells announces the approach of Banjára cattle laden with corn; the leading bullocks are decorated with plumes attached to the head between the horns. Brass sockets tastefully worked are fitted on to the upper portions of the horns, the remaining portions are enclosed with cases; the head has a covering, the neck a collar to which bells are attached; all these are ornamented. The tail pieces and packs are also decorated. Shells enter largely in ornamenting the several pieces, which are tastefully arranged and worked to adorn the useful animal. The costume of the women is very striking and picturesque; it consists of a petticoat made with strips of cloth 6 to 8 inches in width of many colors, of the brightest gayest and most gorgeous hue, which are put together to form this garment. A patchwork bodice of various colors to match the above, and a sheet edged with tinsel or red, thrown over the shoulders, completes the costume. A profusion of jewels of all metals from gold and silver to base brass are necessary to complete the toilet. Large gold nose rings, some jewelled, others plain silver, ear-rings covering the entire ear, strings of beads of all colors and sizes round the neck, the arms covered with bangles and amulets, the ankles decorated with massive metal ornaments to which are attached small bells, add greatly to the novelty of the costume of these peculiar people.

(22.) Long before daylight the trappings of the bullocks are put on and they are laden. The march begins with the leading bullock advancing with waving plumes and tinkling bells; others follow in succession, with a cock perched on the load of one, a hen on another, a child on a third, a kid on a fourth, a litter of pups on a fifth, and so on, until all their livestock and the children of the gang are accommodated. The laden cattle are followed at intervals by a damsel, robed and adorned as above, driving and vociferating to the lazy and unruly under her charge: after a few minutes a man follows, and is heard shouting and talking to the bullocks as if they understood what was said, and castigating them when necessary. Each man carries a weapon of some description to defend himself when necessary.

(23.) The whole band is escorted by dogs which are seen following the men, women or cattle all along the line of march, exercising their vigilance over all. The goats, sheep, cows with their calves, and mares with their foals, bring up the rear accompanied by the aged, sick or infirm of the gang mounted on ponies. The loads are every now and then adjusted, the cattle which entangle themselves among the forest trees, are extricated, and on the Banjára proceeds to his destination with his grain laden cattle, his worldly goods and chattels, his wife, his children, and his livestock; he leaves nothing behind. With his sheet of gunny, which he pitches for shelter from dew and rain, and with all his belongings, he is contented and happy as any other living man in the enjoyment of ease and comfort. Each band of Banjáras elects its own chief, who is implicitly obeyed. The chief settles disputes, and administers justice to all. These people seldom resort to courts of justice. They are an independent, intrepid, hardy race, going through uninhabited forests swarming with wild animals. Their encampments are well chosen, mostly on banks of streams, elevated and open. Their bullocks are picketed in rows, a long rope with knots equally placed 3 feet apart to which are attached halters answers the purpose; the ends of the rope are fastened to piles driven deep into the soil, and the halters secure the cattle. Large fires surround the encampment and are fed and kept alive by the men on guard who watch turn about. The numerous dogs with each gang guard and protect them effectually and will not allow the cattle to stray nor an intruder to approach. The dogs are of a peculiar breed, large, fierce, powerful and intelligent, and are very much attached to their owners. They live with the family and are fondled and caressed by the children.

(24.) Mr. Henry Beverley, Surveyor 1st Grade, was employed during the entire season upon secondary operations. I have already alluded to the assistance I received from him during the azimuth observations at the central station of Karia. With his usual energy and zeal he has accomplished a large quantity of work, having determined the positions of 7 important places, connected 10 Topographical stations, fixed 52 secondary stations and 102 intersected points and villages. His triangles having all three angles observed amount to 53. The heights above sea level of nearly all his secondaries have been determined. In addition to the above he has constructed rectangular pillars over six principal stations and placed them under the protection of the local authorities.

(25.) Mr. Beverley and his detachment have one and all suffered from fever, notwithstanding which he worked on and even took his stand at the theodolite with fever on him. The wavy undulating nature of the country, densely clothed with jungle, having villages scattered here and there screened or rather imbedded in the forest, might have disheartened a less experienced Surveyor in determining their positions. The difficulty of laying down the villages was great and the labor trying; he however progressed steadily and systematically, and the result has been the large quantity of secondary work which is shown in the rough chart accompanying this report.

(27.) Mr. F. Bell, Surveyor 3rd Grade, was employed throughout the season upon secondary work, and has determined the positions of 5 important places, connected 4 Topographical stations, fixed 24 secondary stations and 39 intersected points and villages, and obtained 35 triangles all three angles of which have been observed; and heights above sea level of most of his secondary stations have been determined.

(28.) Mr. Bell and his establishment suffered from fever; at one time almost all in camp, he himself included, were prostrated. He like all the members of this department bravely maintained his ground, treated himself and his men most successfully, and perseveringly advanced his operations notwithstanding the sickness in camp and the difficulties he had to encounter in the prosecution of his labors. He remained out latest in the field and did not close work until the weather became unfavorable.

(30.) Mr. E. P. Wrixon, Assistant Surveyor 3rd Grade, has throughout the season been employed in constructing rectangular pillars over principal stations and handing them over to the local authorities. He has built and made over 17 stations. In addition to this he has accomplished some secondary work in last season's triangulation. He observed at 10 principal and 7 secondary stations, obtaining 21 triangles of which all three angles have been determined, and 4 triangles of which only two angles have been observed, and determined 35 intersected points.

(31.) Mr. Wrixon and his small detachment suffered much from sickness and he lost three men from fever. At Singanáma H.S. he was so ill from fever that he intended proceeding to Colonel Saxton's camp, which was not very far removed from him, for medical aid. A favorable change taking place just then enabled him to continue his work. On his return to Wálter he had another bad attack of fever. He had to go over the ground of the previous season, visiting each station of the Bider Longitudinal Series. The very difficult ground of the Eastern Ghâts which he had to traverse has been described in my last narrative report. I provided Mr Wrixon with lime for 10 rectangular pillars and he arranged for the remaining stations.

(33.) Mr. Beverley having determined the positions of the large towns of Jaipur, Jagdalpur, Korápút and Naurangpur, has furnished the following information regarding them:—

Jaipur.—The town of Jaipur is the seat of the Rája, a semi-independent Prince, the Chief of a tract of country about 200 miles in length and 50 in breadth. Jaipur is situated on low ground to the south of low undulating hills, the most southeasterly of which is Doseabata, and within six miles of the high mountains which surround it on three sides, and there is an isolated hill 2,000 feet in height to the northward. The town is therefore in a hollow and consequently unhealthy throughout the year; it consists of about 1000 huts inhabited chiefly by the retainers of the Rája and traders. A metalled road from Korápút passes through the town from east to west, all the rest are mere village paths; on both sides of this road are large thatched houses with mud walls belonging to traders and influential men; and in their midst is the residence of the Rája, a large upper-roomed paka building with a tiled roof, situated on slightly elevated ground and commanding a view of the town. The residence of the Assistant Agent and Police Officer was to the west of the town; owing to the unhealthiness of the place, this has since been abandoned, by the officials for Korápút on the Ghâts, distant about 15 miles to the eastward. Jaipur is surrounded by several groves of mango trees; these are planted in rows, each about 20 yards apart, with mathematical precision, the trees in each row being the same distance from one another. The place is surrounded by a number of tanks more or less large, one to the west being half a mile in length.

Korápút.—When Mr. Turner was appointed Political Agent of Jaipur in place of Captain Smith, who was obliged to go on sick leave, on account of the notorious unhealthiness of the town of Jaipur, he was given the option of residing on the high plateau which nearly surrounds Jaipur; he took advantage of it and selected the present site about 15 miles east of Jaipur. The Public Works Department is now engaged on a good cart road from the head of the Ghâts to the town of Sálúr, in the plains to the east, which when completed will facilitate considerably the export of grain from Jaipur and Bastar to the sea coast. At present the only available mode of conveying grain is by pack bullocks which makes all grain brought into Vizagapatam, very expensive.

The civil station of Korápút obtained its name from the small hamlet of Kora, "pút" being an affix signifying a very small village, but it is in the lands of both the small village of Korápút and the large one of Khumba; the boundary line between the two villages passes over a small hill in the centre of the town, on this hill is the Trigonometrical station. The latter village was abandoned after the civil station was formed; the site is now occupied by the Police lines and the Sub-Magistrate's Kachahri. The site of Korápút is well chosen, it is in the centre of an extensive tableland, about 2,900 feet above sea level, bare of trees. A large square tank in the centre of the town and to the west of the Trigonometrical station, is being excavated which will supply the station with water. Korápút is in its infancy, the residences are temporary buildings, but permanent ones are in course of construction for the Agent, Superintendent

of Police and for all Government offices. From Koráput to Sálúr, the nearest native town in the plains is 48 miles, of which 25 miles is on the high tableland up to the Ghâts, and 23 miles from thence to Sálúr.

Naurangpur is a pretty considerable town extending for about a mile in length from north to south, but is very narrow; it is situated about a mile from the right bank of the Indrabati river, which takes its rise in the Ghâts and proceeds westward till it falls into the Godávari. During the cold weather it has a depth of 3 to 4 feet of water, but it overflows its banks during the rains, and sometimes destroys the crops a couple of miles on either side. There is but one street through the town of Naurangpur from which branch off very narrow lanes or village paths to the huts; these are of mud walls with thatched roofs, except the Rája's house and the Sub-Magistrate's Kachahri. To the east and west of the town are three large tanks respectively which supply it with water; on the bank of the centre tank, to the east, is the Trigonometrical station. A fine avenue of mango trees planted in four rows extends from Naurangpur to Magigura village about 2 miles.

Jagdalpur is the residence of the Rája of Bastar; his former place of abode was at Bastar, or Juna Bastar, the latter is now quite abandoned, and the site of the old town is a forest: a few small scattered villages at the outskirts of the forest still go by the name of Bastar. The distance from Bastar is 10 miles. Jagdalpur is on the left bank of the Indrabati river which here is deep throughout the year. The town is immediately on the bank of the river, and is inhabited only by the Rája and his retainers. In a large mango tope to the south of the town a weekly market is held, and there is a fine, large tank extending about a mile in length to the west of the town.

Mr. Bell has supplied the following notes:—*Karial*, the residence of a Rája, consists of three to four hundred huts. The Rája's residence is paka, and is built in the form of a quadrangle with a minaret at each corner. One thing I noticed as peculiar while in the Karial Táluk, *i.e.*, the people would on no account give the name of their paternal parent, although they unhesitatingly gave their mother's name. In all my travels this is the first time I have met with this peculiarity, usually it is just the reverse.

Karial is faced on the western side by a marsh extending fully the length of the town (there is first-rate snipe shooting to be had in it) it is very low and surrounded by hills on the south and southwest, the hills run in long ranges. The Táluk of Karial consists mostly of well watered strips of land dotted with hills, and is separated on the west from the Nawagarh Táluk by a high and continuous range of hills about 20 miles broad. It belongs to the Raipur District, Central Provinces.

Sihoa H.S. The hill of Sihoa is considered to be the source of the Mahánaddi River, and like all old places of note it has its legend. The following is what I picked up during my stay:—Once upon a time there lived a Jogi (hermit) in a small cave, still extant on the hill top, where he was supplied with food and water by a little girl, the daughter of one of the townsmen (for it was then a large place and of some importance). One day the child forgot to take the hermit water, which caused her great anxiety and fear; however, when the old hermit saw her distress, he questioned her as to the cause and being told, he ordered her to pass her hand thrice round the "Tombie" (gourd) and then to remove the cover. On doing what she was bid, she found to her surprise the gourd was full to the brim. One day the gourd broke, and being full at the time the contents percolated through the hill, and taking the form of a stream flowed eastward; on perceiving what had happened, the old jogi demanded what the waters meant by imitating the course of most other rivers, about that part by flowing to the east, and ordered it to go to the west; the order was obeyed, and the river having gone a short distance in an easterly direction suddenly turned and proceeded to the westward. Since that time (I could not get the date) a fair has been held annually in commemoration of the occurrence, which is largely attended. A few streamers mark the former abode of the Jogi. The hill has once been fortified, traces of which are still to be seen, and it is naturally rather formidable being almost perpendicular on three sides and consisting of rocks on the fourth side; on nearing the top of the hill it becomes very steep, and the path admits one person at a time only, being very narrow, and is completely commanded by a couple of overhanging rocks of great size like bastions. Before the use of large guns this place must have been very formidable; it was occupied by a band of marauders. Prior to the country becomming settled, Sihoa is said to have been guarded by a hundred horsemen and fifty foot, but this force has been gradually reduced to a handful of police; Sihoa is now in the Raipur District of the Central Provinces.

Extract from the Narrative Report—dated 15th July 1873—of H. KEELAN, ESQ., Deputy Superintendent 3rd Grade in charge Bilaspur Meridional Series.

(2.) The party reached Jabalpur from Head Quarters on the 9th November, and marched from thence on the 20th to the Raipur district to resume operations, and arrived at the tower station of Mahásamand on the 16th December, where it was intended to observe a second verificatory Azimuth (the first was taken about 50 miles higher up at the tower station of Pathaidi) but owing to the low swampy nature of the country around Mahásamand a suitable referring mark could not be found in the direction required, and in consequence the azimuth observations were taken at the hill station of Remai, 12 miles lower down, a station equally free from any apparent local disturbance. On the 20th, observations to δ Ursæ Minoris were begun, and completed on the 27th of December. The weather throughout these observations remained fair, though fears were entertained during the preliminary arrangements, that it would not be so, as it was daily cloudy during this time.

(4.) Immediately the observations at Remai hill station were completed, Mr. Surveyor Clarke was detached to build up all the platforms and cut roads for the large theodolite at the several hill stations selected the previous season; in the meanwhile, I returned to the tower station of Mahásamand to begin the final observations there.

(5.) During the month of December final observations were completed at Mahásamand station.

(6.) During the month of January final observations were completed at the hill stations of Khalári, Guhia, Remai, Jogi and Jatia.

(7.) During the month of February final observations were completed at the hill stations of Malewa, Bamnai, Pendra and Deodongri. These two last points define the closing side of the northern and southern sections of the Bilaspur Series.

(8.) The final principal angles were commenced on the 30th December, and in order to close the work on the side of junction (Pendra H.S. to Deodongri H.S.) from the north, before the signal parties of the southern section came up, the observations were carried on steadily to the 17th February; but notwithstanding the effort to obviate clashing, a short delay of one day did occur to Mr. Rossenrode, when the above named stations were finally cleared by me for the observations connected with the southern section.

(9.) In the instruction conveyed in your Office letter of the 21st October last, a second Azimuth was to be observed at Pendra H.S., provided its position was free of local disturbances; but I had strong doubts, viewing the country from the north in the early part of the season, of securing these observations, on account of the close proximity of a formidable mass of elevated hills running south and east of Pendra, 15 miles off, and on which the station of Deodongri stands. It was eventually found on closer inspection of the country in the neighbourhood, that it would not answer for either an Azimuth or Latitude station, and the project was therefore given up. The camp then broke up at Pendra and marched up towards Jabalpur, where it arrived on the 24th March, and thence proceeded to Chanár (Chunar) *viá* Rewah and Mirzapur. The march was long, tedious and trying; the country travelled over could not have been less than 500 miles.

(10.) There is no secondary triangulation executed in the last season's portion of the principal operations as there are no defined points in the country of any kind whatsoever. It is without exception the wildest tract it has ever been my lot to work in, at the same time very sparsely inhabited, on account of the numerous wild animals that overrun the district, especially wild buffaloes. The Native Doctor Moti Ram would have been killed by one of them, a solitary infuriated beast, the terror of the neighbourhood, but for the ready assistance he received from villagers who were at hand to rescue him. On the other hand, the party had only two assistants. Mr. Surveyor Clarke was employed in building platforms, cutting roads, preparing materials for building rectangular pillars and transferring them to the native officials, and Mr. Assistant Surveyor Clancey was employed in the office and in recording observations in the observatory.

(11.) The men of the Native Establishment suffered much from jungle fever; the average daily number of sick were 15, nearly all through the season.

Extract from the Narrative Report—dated 31st July 1873—of W. G. BEVERLEY, ESQ., Assistant Superintendent 2nd Grade, in charge Assam Valley Triangulation.

(2.) The camp started from Gowhatty on the 25th November. I had intended taking the field early in November as stated in my Report for 1871-72, but was unable to do so before the above date, owing to the lateness of the rains, the delay of the men in rejoining from leave, and the necessity for entertaining new men.

(4.) As there were no stations ready in advance for the final observations, I took up secondary triangulation, while the assistants were employed in selecting and clearing rays, and in building pillars. I commenced work at Bishnáth on the 8th December, and visited the hill stations of Kamakia, Kandali and Longboai for the purpose of fixing the Civil Stations of Naugong and Tezpur, such of the Revenue Survey platforms as could be seen and all the prominent peaks to the north and south of the Bráhmáputra River.

(5.) A good number of peaks were observed to at Kamakia H.S., on the 16th December; but by the time I reached Kandali on the 22nd, all the ranges to the north were completely obscured. The firing of the grass jungles had begun earlier than usual, the smoke from which, combined with the heavy fogs that sometimes did not rise up from the valley till 2 and 3 P.M., prevented my getting much secondary work. Several days were spent at Kandali and Longboai without any results, and I proceeded to take up the principal work, visiting the Revenue Survey station of Kamargáon, *en route*, where some observations to peaks were obtained after three days very heavy rain.

(6.) Final observations were commenced at Cheniabinshon H.S. towards the end of January, when the pillars at Golághát and Bor-Chapri had been built up to the required heights. The Nikori-Chapri pillar having fallen down soon after completion, I suspended the principal observations at Kankochan H.S., on 12th February, and took up approximate work and ray clearing, returning to Kankochan H.S. on the 25th with a view to fixing some peaks—weather permitting—while the pillar was being built. The observations at this station were completed on the 2nd March. From the unavoidable delay in building up the pillars, the angles at each station could not be all observed at once, and it became necessary to visit some of them a second and third time. The Bor-Chapri pentagon was out of hand on the 2nd April: the observations at two stations of this figure were taken with the 12-inch theodolite, in consequence of the injury occasioned to the 14-inch on the Golághát tower, and which was reported to you at the time. The results obtained from this instrument were very satisfactory, observations being taken on ten zeros.

(9.) The principal work for the past season is only one pentagon: this is an exceedingly small out-turn, and is due wholly to the approximate work not being well in advance. I have in last year's report drawn attention to this circumstance, and to the difficulties peculiar to Assám in selecting stations, to which may be added the very great delay in building stations from the frequent heavy falls of rain, commencing in February and continuing with few breaks throughout the field season. If the approximate work had kept well ahead of the final observations from the first year of the survey, a larger out-turn might have been more reasonably expected than we have been able to show.

During last season, Mr. O'Sullivan has been able to select six points ahead on the left bank of the Bráhmáputra, and will probably have three more in connection with them, selected on the right bank, very shortly after taking the field. I purpose employing two assistants for a short time in building the stations, and hope to have the approximate work for the future always sufficiently in advance of the final work, and thereby have a larger out-turn.

(10.) The secondary work has completely defined the lower range or Dafla hills, on the north bank of the Bráhmáputra and east of 93° 25′, and also fixed several peaks on the inner ranges between Long. 92° 30′ and 94° 15′. These points would be useful to the survey intended to define the British boundary to the north, or to any party that may accompany the rumoured expedition into the Dafla hills. Four peaks on the snowy range also have been added, but as these were only seen twice, some uncertainty for the present exists as to their positions. Three Revenue Survey stations have been connected with the G. T. Survey and some more would have been fixed had they been accessible, and not built in the depths of grass and forest jungle. In the Lotha Nága hills four or five peaks have been laid down; some of these are common to the Topographical Survey carried on last season, and serve to make a sort of connection between the two surveys. Two hills in the Civil and Military station of Tezpur as well as the Church and Lunatic Asylum have been fixed, also the Assistant Commissioner's house in the Sub-Divisional Station of Golághát. The Civil Station of Naugong could not be fixed for want of time, but this may be done in the ensuing season.

(11.) The approximate work, it will be seen, has been carried up to near Sibságar. Mr. O'Sullivan reports that the jungle on the right bank of the Bráhmáputra River, on the Majhili island, is very heavy and will be a source of considerable delay. It would therefore be advantageous to keep along the left bank up to Dibrugarh, only crossing over when the forest on that side becomes heavy. The side Bor-Ali to Gauriságar will be best adapted for extension up the valley, and the side Gauriságar to Cintamunigarh for turning into the hills. There does not appear to be any difficulty in the triangulation being taken once more into the hills at this point, as they are inhabited by more tractable tribes, and there are numerous tea gardens scattered along the boundary, and even beyond it. I would therefore propose for the ensuing season that the survey be carried along the hills entirely, after we have once entered them, or have one flank resting in the plains should there be any political objections to our going further into the interior.

(12.) The country traversed by the triangulation last season has been already described. The same difficulties in progress were experienced in the clearing and cutting of rays through patches of heavy forest and reed jungle. The country ahead, on the left bank as far as the approximate work has extended, Mr. O'Sullivan describes as less difficult; some of the rays will require little or no clearing. The stations too, have been selected on high mounds and old temples, which will be serviceable in reducing the heights of the pillars.

(13.) Inadequate carriage has been the occasion of much delay. As local labor was not available, the elephants of the party were employed to convey materials for building, provisions for the establishment and also to crush down the jungle on the rays. If two or three more elephants could be attached to the party much inconvenience would be avoided. It was necessary last season when marching from one place to another to make frequent halts, while the baggage had been sent ahead, and unfortunately neither elephants nor other animals could be obtained on hire in the Sibságar district by which time might have been saved.

(14.) Mr. Harris was employed throughout the season in building stations. Those at Golághát and Bor-Chapri were respectively raised to a height of 23 and 24 feet. The pillar at Madaigáon was built to a height of 35, and Nikori-Chapri to 25 feet. That at the latter station had to be built up a second time.

(15.) It was found necessary to erect a pillar 12 feet high on the Nigri Ting hillock, in order to overlook the numerous trees scattered over the tea gardens which extend all round and up the slopes. An ancient, high temple, surrounded by trees, crowns the summit of this hillock. It was proposed to erect a platform on the top of this temple from which a very extensive view is obtained, and by clearing the ray between it and Golághát, a double pentagon would have been obtained. The guardians of the temple gave at first their consent to our proposal, but subsequently declined on superstitious grounds to permit what they considered a desecration of the shrine. The site for the station was therefore selected outside the wall of the enclosure, on the slope towards the N. W. corner.

(16.) This pillar was completed by the 13th April, and Mr. Harris crossed the Bráhmáputra and took up the building of Rodonga and Bekhuli Mukh stations.

(17.) Mr. Harris' progress has been rendered very slow from the wet weather which prevailed almost throughout the season. The bricks after being moulded had to be protected from rain, and although dried in the sun imbibed moisture so very rapidly, (the fall of the Nikori-Chapri pillar was due entirely to this circumstance), that it became necessary to kiln-dry them before they could be used. The soil too, was in some places so ill adapted for making bricks, that they had to be moulded and baked at long distances from the stations, and conveyed thence by elephants and boats. Mr. Harris, with his usual good management, employed his materials to the best advantage, and with due regard to economy.

(19.) Mr. O'Sullivan was employed on the Approximate series. He commenced work early in December in re-clearing and carrying final rays between the stations selected the previous season.

(20.) I have mentioned in my last report the delay in cutting through the forest jungle of Assám. This forest fortunately occurs only in patches on a ray, and some idea of its nature may be formed from the fact of one ray last season having occupied Mr. O'Sullivan with a party of 25 cutters 36 days to carry. There is also much loss of time in re-clearing final rays a second season, as the grass and bamboo jungle grow very rapidly and heavy during the rains.

(21.) On completing ray clearing, Mr. O'Sullivan took up the selection of stations in advance at the beginning of March; and by the 3rd April had carried the Approximate series up to within 6·4 miles of Sibságar. Exclusive of Nigri Ting, 6 stations have been selected and fixed on the left bank of the Bráhmáputra. These points could only be determined on after reconnaissance, since no information of any kind could be obtained from the Assámís, who appear to know little or nothing of the country beyond the bounds of their villages, and the maps we relied upon were rather incomplete in some necessary details.

(22.) Mr. O'Sullivan reports the country on the left bank, in the Jorhát division, to be a little more open than on the other side, on the Majhili island, and to have scattered about high mounds—the sites of villages, old temples abandoned or ruined, and high tank banks, with

numerous paths and roads. He has shewn considerable judgment in his selection of stations in advantageous positions and convenient of access, and in carrying the series over to the left bank entirely, at a point where it may be readily advanced into the hills or extended up the valley.

(23.) Mr. O'Sullivan crossed the Bráhmáputra on 14th April and selected and fixed Bekhuli Mukh station, and would have probably completed the selection of the three remaining stations on the northern flank, had not his progress been stopped from want of provisions. No assistance could be obtained from the Mauzadárs who were invariably away from their Mauzas, and applications to the district officers were of no avail. It is a remarkable coincidence that the Mauzadárs of the Sibságar District were always absent at the Sadr Station when called on by the surveyors for assistance. This is the second season that Mr. O'Sullivan and his establishment and elephants have been, as it were, starved out of the Majhili.

It will be necessary next season to carry supplies for men and animals in boats from below, and to make such other arrangements as may render it possible for us to be wholly independent of assistance from district officers or Mauzadárs.

(24.) Mr. Hughes, immediately after entering the Department, was posted to this Survey. He accompanied Mr. O'Sullivan to the field and was trained in ray carrying, and in the use of the theodolite. He joined the main camp for a short time, and acted as Observatory Recorder. Mr. Hughes has shewn much intelligence and aptitude in learning the duties of his profession, and will in time become an efficient surveyor.

(25.) The assistants have throughout the year worked cheerfully and well, and in spite of hardships and privations, and various physical discomforts and annoyances incident to field life in Assám, have continued to evince a zeal for their duties.

(26.) The field season has been unhealthy; nearly every one has sufferred more or less from malarious fevers and other complaints, returning to quarters much debilitated. One death only took place in the establishment.

(27.) The party returned to quarters at the end of May, remaining out a little longer in the field than was necessary with a chance of obtaining more work if possible, but the weather was quite opposed to progress. The low ground was under water about the 25th April from the continuous heavy rain; little work was got after the 16th of April. Unless prevented by untoward circumstances, the party will leave recess quarters towards the close of October so as to be on the ground early in November.

(28.) The accompanying chart on the scale of 8 miles to the inch, shews all the work of the Assám Valley Survey from its commencement. There is a great blank west of Long. 93° 0′, and I propose to take up secondary work from Silang (Shillong) and carry the observations up the valley so as to fix points on the ranges to north and south and fill up this blank. These observations could be carried on until the principal stations ahead are ready.

Extract from the Narrative Report—dated 27th June 1873—of Lieut. M. W. ROGERS, R.E., Assistant Superintendent 1st Grade, in charge Jodhpur Meridional Series.

(2.) During the recess season I received instructions that the party was to be employed during the next field season in Rájputána, on a Meridional Series, emanating from the Karáchi Longitudinal Series, and proceeding north, on the meridian 72° 30′ to meet the Sutlej Series. As the preparations of the last field season had been made with a view to doubling the Great Arc in parts between Bider and Sironj, the whole arrangements for the season had to be changed.

(3.) There still remained some stations of the last year's work to be closed, and a portion of triangulation to connect Karnúl, which Mr. Bond had been obliged to abandon last year from ill health: besides this, in the selection of the Arc, north of Bider, there were two groups of Zenith Distance Stations which had been selected for Captain Herschel last season, and at which he had observed. Until these were connected with the triangulation, his observations would be useless, I therefore despatched Messrs. Torrens and Oldham, with as many men as I could spare, as early as it was possible after the Monsoon, Mr. Torrens to take up the Karnúl triangulation and Mr. Oldham to close as many stations as he could before I required his services in the field.

(4.) The main party reached Ahmadabad on the 8th November. Having made all arrangements for the season's carriage, and left the great theodolite in charge of Lieut.-Colonel Griffiths,

R.E., the Executive Engineer, I marched *viâ* Dísa to Erinpura where the guard and vakíl for the party had been sent by the Jodhpur Government.

(5.) On the road, I visited the Station of Mount Abu, to see if any place could be got for the recess quarters of the party, but I found that the demand for accommodation was far in excess of the supply. After leaving Erinpura, I employed myself in conjunction with Messrs. Price and Bryson in selecting stations and laying out the Approximate Series.

(6.) As soon as this was sufficiently advanced, the great theodolite was brought up from Ahmadabad by Mr. Oldham, and on the 31st January I commenced the principal observations at Súnda H.S. of the Karáchi Series. The observing was now pushed on as rapidly as possible, for the best portion of the observing season had been spent in the necessary preliminary operations. Delay was experienced twice (two or three days each time) on account of sudden and impenetrable mists, and at the last station of the season I was detained eight days observing two angles, and this was the first week in April, and the weather after this never cleared; so I think it will be necessary in this series to begin work sufficiently early to get the observations finished by the end of March. Observations were closed at Dodo H.S. on the 8th April; I thence marched southwards, closing, in conjunction with the detached parties, all the stations observed at during the season. The detached parties having joined the main camp on the borders of Márwár, I marched *viâ* Dísa to Ahmadabad, reaching Púna on the 8th May.

(7.) The following is a brief outline of the season's work.

The Approximate Series was commenced and carried forward 147 miles, 25 principal stations being selected and built; 14 principal stations were visited for observations and 44 angles observed, fixing 12 new principal stations by 14 triangles, embracing an area of 3,706 square miles, and extending the series northwards 95 miles. An azimuth was observed at Thob H.S., in Lat. 26°., to two circumpolar stars.

7 Zenith Distance stations were fixed on the Great Arc for Captain Herschel; besides, a good proportion of secondary work was done—58 points fixed—embracing an area of 2,443 square miles, outside the principal triangulation.

All secondary and intersected points have been fixed in height as well as in position.

As the observations, from which the season's work is in a great measure judged, were not able to be commenced until two months of the season had passed, I trust you will consider that the progress of the party has been satisfactory.

(8.) The country through which the season's operations have been carried is sandy and flat, with an elevation towards the east of about 700 feet, diminishing towards the west and the Luni river to 300 or 400. South of the Luni river small detached ranges and isolated hills are numerous. Their sides are very steep and covered with jungle. Many of them rise to a considerable height above the plains, several to over 2,000 feet.

(9.) Jallor, which is the principal town in this part, has a large fort in fair preservation, with a garrison and several pieces of old-fashioned cannon; it is on a precipitous hill, rising 1,350 feet above the plain, it is however commanded by a still higher peak of the range. I was allowed to place a mark in the fort and observe from it, and was told that I might build a principal station in it if I pleased. To the east, towards the Luni (which flowing west, across the series, turns south and skirts its western flank) the country becomes barren and sandy, generally nothing but sand hills covered with low shrubs, water scarce and brackish and villages few and far between. The hills disappear, and save the sand hills the country is level for 70 miles, as far as the Balmír hills.

(10.) North of the Luni the country becomes still more sandy and desolate, and the water is almost entirely brackish. Near Pachbadra there are extensive salt works, but there seems to be hardly any cultivation, and often such as there is, appears to have been destroyed by locusts. These were very destructive last year. The people dig trenches, square in section about one foot wide and deep, for miles around their fields. They say that when the young locusts, which will be every where about this next season, are born, they make for the fields, fall into these trenches and being unable to fly or climb the perpendicular sides, they perish in them.

(11.) There are but few villages which possess a well of fairly drinkable water, and the people supplement the supply by making small reservoirs which they call "tankas"; these are cylindrical, about six feet across and eight or ten feet deep, and are plastered with a coating of fine polished chunam; in these they collect rain water and covering them with brushwood &c., leave them until the well supply fails.

(12.) Towards the end of the season the party suffered a good deal from the badness of the water, and I am afraid that matters will be worse as the series advances.

(13.) The Jodhpur Darbár sent with me a guard of sepoys, sowárs and a vakíl, and also sent a vakíl to Mr. Price. Captain Roberts, the officiating Political Agent, also sent one of his establishment with me. Thanks to these helps I experienced no trouble in carrying out my work, and I have never had a field season in which I have met with so little hindrance or annoyance. My best thanks are due to the Jodhpur Darbár for their help to myself and my assistants.

(14.) Although there are a good many Bhîls and other thieves about, I only had one case of robbery from my men in Márwár, and in that case restitution was promptly made. In Sirohi however one of my peons going for supplies was attacked and robbed on the high road in open day, and my claims for compensation were rejected by the Political Agent for Sirohi, on the ground that the men had not engaged a Bhíl to protect them; this decision considerably increased the expenses of the signal parties, as, after it, I had of course to sanction their hiring one of the dangerous class to protect the Government property when away from the main camp.

(15.) Mr. Priec had charge of the Approximate Series and pushed it forward with great zeal, sparing himself, as usual, no trouble to complete his work satisfactorily. He selected 22 principal stations, built 9, and closed 5, and showed himself in every way worthy of the promotion he received just before taking the field.

(16.) Mr. Torrens completed the Karnúl triangulation (an area of 473 square miles) and fixed that station. He then marched northwards and fixed two groups of Zenith Distance stations for Captain Herschel, in doing which he re-traversed the whole of the heavy march spoken of by Captain Herschel in his last report. On his road he closed 26 stations of the Great Arc Series. This was Mr. Torrens's first season at independent observations, and he had, unfortunately, to contend against unusual difficulties; the Zenith Distance triangulation had been laid out for the great theodolite, and the rays were many of them too long for the powers of his instrument and signallers, and before he finished his observations, he experienced the usual misty weather. His instrument was a 10-inch theodolite, and his average triangular error 2″·5. The health of his party was very bad at the commencement of the season, more than half his men being generally useless from fever; in addition, cholera was prevalent in the Karnúl district, but happily his camp escaped.

(17.) His Highness the Nizám's minister kindly attached Mansabdar Muhammad Faiáz-udín Khán (who was with me last year) to Mr. Torrens's camp, and thanks to his exertions, every aid and assistance was rendered to the camp. I and my party are very much indebted to the Resident and His Highness the Nizám's minister for their kindness during the last three field seasons.

(18.) Mr. Bryson joined on the 1st October from No. 2 Extra party; he was employed during the season on the Approximate Series, selecting and building. He selected 1, built 16 and closed 3 principal stations, and worked throughout the series steadily and well, affording great help to Mr. Price and myself in our exertions to get the series well started this season. I have named him to you for promotion when a vacancy occurs, and his conduct this season quite entitles him to my best recommendation.

(19.) Mr. Oldham, during the first portion of the season, was employed in closing stations on the Great Arc. He then joined me and aided in the Approximate Series. He brought the great theodolite from Ahmadabad, and acted as observatory recorder throughout the observations; he worked well during the recess and has steadily improved himself in all branches of his work. He is now a good recorder and useful assistant, and I have every reason to be satisfied with him. Besides his ordinary work he closed 6 principal stations.

(20.) During the last recess 2 double polygons and 1 very complicated compound figure were computed, together with all the secondary work of the principal and Haidarabad Minor Series and the greatest portion of the Kadapa (Cuddapah) Minor Series. Owing to the alteration in the locality of the work, and the distance the party had to go, a small portion of the season's calculations remained unfinished: these will be brought up this recess.

Extract from the Narrative Report—dated July 1873—of Major B. R. BRANFILL, Deputy Superintendent 2nd Grade, in charge Madras Party.

(1.) The recess of 1872 with which this report commences, was a short one of 4 months, beginning only about the middle of June 1872, on the return of the party from the field where it had been detained by bad weather and prevented from completing the observations required to finish the Mangalur Longitudinal Series. All the stations had been visited, but 3 or 4 angles were incomplete when the onset of the Western Monsoon obliged the observing party to abandon the field.

Recess of 1871-72.

This accounts for the comparatively small out-turn of results obtained, and for the fact that no preliminary chart was sent in. As however the office work was continually interrupted and

hindered by the ill health of the members of the party, contracted in the jungles and "terai" of the Western Ghâts during the previous season, little, if any more could have been done than was done.

Uncommon difficulty of the coming season's work anticipated.

(4.) I here beg to refer to paragraph 42 of Lieutenant Trotter's annual narrative report dated 29th August 1867, in which he states that the progress of the series, to the southward of the stations he closed on, Chandraguti-Hallibail, must be slow in future, in consequence of the natural difficulties of the country and climate.

Details of the difficulties to be met.

(5.) The season's work before us was indeed one that promised to task us to the utmost, and I was by no means sanguine of success.

The Western Ghâts.

The series lay for above 100 miles along the crest of the Western Ghâts, a tract of hills and forests, clouds and mists, rivers and torrents.

No cross roads nor villages.

Three or four roads (two of them bridged) cross the line of the series from east to west, but there are no cross country roads in the direction of the series, *i.e.*, north and south near the Ghâts, nor any villages in the country, except a very few on the main roads.

The population is exceedingly scanty, dwelling in houses or huts scattered singly over the country, one or two at each patch of cultivation.

Revision of the Approximate Series necessary.

(6.) I had already determined to remodel the Meridional Series, north of Mangalur, rejecting the stations of the original (Mr. McGill's) Approximate Series below the Ghâts, and carrying the series entirely above (*i.e.* east of) them. Part of this I had laid out last season, and part of the old Approximate Series of the Bombay Party could be incorporated; only, after last year's experience, it was necessary to re-examine all the rays, more particularly so as six or seven years had elapsed since their first selection; about one-third of the whole distance remained to be selected afresh. 5 stations had to be examined and repaired, 7 built, and 20 to be closed.

The two series terminating at Mangalur now completed.

(7.) I am happy to state that the whole of the principal triangulation, Meridional and Longitudinal, terminating at Mangalur has now been finished, with a large proportion of secondary points, and I can confidently assert that had I retained the original plan of the series, by which the Ghâts must be crossed and re-crossed several times, it could not possibly have been done this season.

Success due to a favorable season and the assistance of an extra Officer Lieutenant McCullagh, R.E.

(8.) I attribute our success to the good fortune of a comparatively favorable and healthy season, and perhaps chiefly to the fact of my having the assistance of Lieutenant McCullagh, R. E., to whom I entrusted the conduct of the principal observations with the 24-inch theodolite which enabled me to complete the Approximate Series in person, and to spare an assistant for the minor triangulation to the southward intended to fill up the great gap in Colonel Lambton's triangulation between Kannár (Cananor) and Paniani.

(9.) Taking advantage of the first break of fine weather in the North-East Monsoon rains, the Party took the field at Bangalor on the 20th October, and after a march of about 300 miles commenced operations in the middle of November on the terminal side Chandraguti-Hallibail, of Lieutenant Trotter's triangulation of 1866-67.

Operations begun at the north end of the series.

(10.) We commenced work at the northern extremity of the season's task, to avoid, as much as possible, the region where the North-East Monsoon clouds and rains are heaviest; and this is supposed to be worse the farther south you go in this part of India in November.

Disposition statement of the party.

(11.) The disposition of the party was as follows:—I myself, with a party of 9 klassies, undertook the examination and completion of the Approximate Series. Lieutenant McCullagh had charge of the main party of 27 klassies and lampmen and conducted the final observations with the 24-inch theodolite, with Mr. Laseron as recorder and office assistant. Mr. Mitchell with a party of 11 klassies, I sent to complete the final observations of the minor series to the south-east of Mangalur which he had laid out and commenced last season, with the 12-inch theodolite.

Messrs. Norris and Potter had each charge of a building party consisting of a mason and 2 klassies, and were sent to examine and repair the old stations used, to build the new ones, and finally to close the whole of them as soon as done with; the former on the west, and the latter on the east flank and centre of the series.

The Approximate Series completed by Major Branfill.

(12.) I took up the Approximate Series at Hukli H.S., examining and repairing the station, which had been already selected and built by the Bombay Party; afterwards visiting and observing in succession the stations of Hugadi, Sidéshwar, Kodachádri, Bissali, Sidéshwar, Hebbe, Walkunji and Sidéshwar.

I rejoined the main party at Ságar, on the 3rd January, having marched 481 miles (42 marches) in the 7 weeks, besides ascending and observing at 7 hill stations, each about 1,200 feet above its base; 17 of the marches being across country, and mostly performed on foot.

Who then joins the main, or observing party.

(13.) Meanwhile, Lieutenant McCullagh with the main party had completed observations at 5 principal stations, each over 1,000 feet high and 4½ marches apart, besides having had to descend and re-ascend one of the ghâts or passes to the coast.

Lieut. McCullagh's progress with the main party, observing.

(15.) After my joining the main party, Lieut. McCullagh continued the principal observations and conduct of the single parties &c., whilst I assisted him in the observatory, superintending our progress and the operations in general.

Lieut. McCullagh chief observer, Major Branfill assisting and superintending.

(16.) There being no roads between many of our stations, we had on several occasions to leave our camp and baggage for periods of a week or two, and on one occasion the main party was for three weeks separated from the camp and its supplies.

(17.) During the ten weeks ending 14th March, final observations were completed at 11 hill stations, each 1,350 feet high, on the average, and 4 days' marching apart.

Amount of work done by main or observing party.

42 principal angles were observed, giving an average of 1·4 angles per diem for each day's (and night's) observing.

(18.) Two sets of Azimuth observations were requisite, but in order to push on the principal triangulation to the utmost, and ensure its completion this season I had postponed them to the last.

You were able to send me a spare 24-inch theodolite by sea to Mangalur for the purpose; this I proceeded to use myself, whilst Lieutenant McCullagh, after completing the principal triangulation, proceeded to Koramár H.S., one of the Zenith Distance stations (in latitude 14° 8′) observed at during the previous season by Captain W.M. Campbell. He accomplished his task on the 27th March and reached Bangalor on 15th April, thus closing a very fortunately successful season's work.

Azimuth observations at 2 stations.

Koramár Azimuth completed, and return of main party. Principal triangulation completed.

(19.) On the 8th March when the observations at Anúr H. S., the last station but one, were finished, I left the main party and marched to Mangalur, 100 miles distant, which with a fair road I accomplished in six days, arriving on the 14th March. It was necessary to raise a platform in order to observe from. This work occupied 4 days and was only just completed on the 19th, when the steamer arrived with Barrow's 24-inch theodolite (No. 1) which I landed, set up and began observing with, the same evening.

Major Branfill leaves the main party for azimuth at Mangalur.

A complete set of circumpolar star observations for Azimuth to α Ursæ Minoris (Polaris) at western elongation (the same star used by Lieutenant McCullagh for the Azimuth at Koramár H.S.) was finished by the 24th of March, and on the 25th I packed up and despatched the instrument back to Calcutta by steamer and left for Bangalor the same day.

Mangalur Azimuth completed.

(20.) Altogether 59 principal angles have been observed this season at 17 stations, of which 7 were newly selected and built, forming a double series of triangles, comprising one double polygon, one hexagon, and two quadrilaterals, covering 3,330 square miles, and extending the Mangalur Meridional Series, which is now complete, 105 miles from north to south, and at the same time completing the Madras and Mangalur Longitudinal Series at Mangalur.

Brief, general statement of field work done.

Two Azimuths of verification have been observed, and 74 secondary points, with their heights complete, fixed, embracing an area of 4,064 square miles exterior to the principal triangles. About 150 barometric heights have been observed, and all the principal stations finally closed and delivered to the local civil authorities.

(21.) 8 stations of Colonel Lambton's triangulation were found, with (⊙) mark-stones in position, and duly occupied or connected. 10 other points of the old survey have also been connected, but as no station (⊙) marks were found their identification is not exact.

Connection with Colonel Lambton's stations.

(22.) I have compared our (the Madras Party) mean preliminary geodetic values of the final side Chandraguti-Hallibail, derived from the Calcutta Base (*viâ* Madras and Mangalur) with those of the Bombay Party derived from the Bider Base, with the following results—which are the closing differences or errors generated in a circuit of 1,050 miles of principal triangulation—the Meridional Series extending 350 miles north and south, and the Longitudinal Series 170 miles east and west.

Comparison of values of the common terminal side with those of the Bombay Party 1866-67.

Closing difference, or circuit error linear = 0·1 ft. = 0·06 inches per mile.
" " " " in latitude 0″·07 = 7 feet.
" " " " " longitude 0″·19 = 19 feet.
" " " " " azimuth 3″·09
" " " " " height 5 feet.

(23.) With regard to the last item, I have farther to remark that our heights in this (Chandraguti) neighbourhood are about 40 feet *less* than Colonel Lambton's published values of the same points, which is about the same difference in amount and sign as was obtained by a similar comparison of the heights of common stations of the Great Arc north of Bangalor; on the other hand, near Mangalur, 100 miles south of Chandraguti, our heights are 40 feet *greater* than Colonel Lambton's values of the same points.

Comparison with Colonel Lambton's heights near Chandraguti.

(24.) I have not the means of making a rigorous comparison with Colonel Lambton's geodetic values of his stations near Mangalur, but I am able to state that his value of the longitudinal arc, Madras—Mangalur, is 38′ greater than ours, just about double of what the difference was midway, near Bangalor, and in the same direction.

Comparison with Colonel Lambton's values near Mangalur, in longitude.

(25.) In latitude our values agree much more nearly with Colonel Lambton's, but there appears to be a slight cumulative difference. I have still less means for making an exact linear comparison, but I have some reason to suppose that Colonel Lambton's unit of length was too great and his numerical values of the sides of his triangles therefore too small, notwithstanding the fact that his value of the longitudinal arc is, apparently, too great.

In latitude and distance.

(26.) Reverting to a comparison of heights, whereas in the vicinity of Bangalor Colonel Lambton's values (derived from the sea at Madras like ours) were *greater* by 30 to 40 feet, near Mangalur they appear to be 40 feet *less* than ours. I have been unable yet to seek the source of this discrepancy.

In heights.

(27.) On referring to Vol. X of the *Asiatic Researches*, article IV page 382, his closing error (+ 8·6 feet) when corrected for an error, which Captain Herschel detected and has pointed out to me, viz. the omission of a minus sign before 22·6 feet (the trigonometrical height of his final staton) appears to be — 36·6 feet referred to low water mark, say —34 feet referred to mean sea level; whence our values would appear to be about 6 feet too great.

A mistake in the published statement of Colonel Lambton's closing error.

(28.) But we have another and independent reference to sea level. In November and December 1869 Captain Basevi, R.E., determined the sea level at Mangalur by a month's observations of high and low water, and referred it by levelling to some permanent masonry buildings. Last year, under my directions, Mr. Norris connected our Mangalur station with these, and with some new permanent stone bench-marks, placed and marked for the purpose, by a line of levels which has been checked by the Executive Engineer, and found to accord well with his own. I have therefore some confidence in stating that the Mangalur (pillar) station, near the Light house and Idgáh, is 186 feet above mean sea level, (the ground level there being 174·6 feet). But our trigonometrical value of the Mangalur station, derived from sea level at Madras is 196 feet, whence it appears that our values are 10 feet too great.

G. T. S. heights tested by reference to the sea level at Mangalur by levelling.

Closing error of new G.T.S. heights = + 10 feet

(29.) I am inclined to attribute this large closing error of 10 feet in a great measure to sudden variations in the local deflection of the plumb-line in the sides (of triangles) between stations above and below the Ghâts: and this view is perhaps partially confirmed by the abnormally high factor of refraction obtained in these cases.

Cause of large closing error suggested

(30.) From the configuration of the country I should expect to find greater easterly and north-easterly attraction (*i.e.* westerly and south-westerly displacement of the true Zenith) at the stations on the western edge of the Mysor highlands, which, as it were, overhang the low country, than at stations situated well out in the low lands, west of the Ghâts, or at highland stations some distance inland, *i.e.* east of them.

Considerable variation of local and mountain attraction to be expected.

(31.) Lieutenant McCullagh, R.E. I have much pleasure in reporting the valuable assistance I have received from this Officer. He has invariably carried out my wishes and directions, and has conducted the laborious duties entrusted to him to my, and I trust to your, entire satisfaction.

Lieutenant J. R. McCullagh R.E., Assistant Superintendent 1st Grade.

As a test of his ability to conduct the operations, and of the quality of the work obtained I need only refer to tabular statement II attached, from which it appears that although the mean triangular error is large (0″·65), as has hitherto generally been the case with the 24-inch theodolite (Troughton and Simms' No. 1, *altered*,) in use with the Madras Party, yet

the probable error of the angles obtained this season is only ± 0″·144, and the mean of all 75 angular corrections computed 0″·24. I trust you agree with me in thinking this highly creditable to Lieutenant McCullagh's powers of observing and carefulness, this being his second season's practice with a 24-inch theodolite.

I beg to express my obligations to Lieutenant McCullagh for the ready and cheerful way in which he has backed me up in completing the series, and I repeat that without his assistance, I do not think it could have been effected this season.

Mr. J. W. Mitchell, Asst. Surveyor 1st Grade.

(32.) Mr. J. W. Mitchell, owing to a variety of adverse circumstances of which rainy, cloudy and hazy weather were the chief, has a very small amount of triangulation to shew for the season's work.

He visited 7 stations and completed only five triangles.

It must be allowed that the country (Kurug and the Western Ghâts) was difficult, the weather extremely bad or unfavorable, and the rays unusually long: his signalmen suffered from fever and were frightened by wild beasts.

I am glad to state that his observations seem to be very good, the average maximum difference between the extreme values in fifteen measures of each angle being 7″·4, and his mean triangular error 4″·6 (see table IV.)

Mr. O. V. Norris, Asst. Surveyor 3rd Grade.

(33.) Mr. Norris accomplished the task assigned to him. He examined and repaired 2 old stations, built 2 new platform stations, and finally closed and delivered 9, (about 50 days' work). He ascended 13 hills, each about 1,500 feet high, cleared or made about 12 miles of pathway and marched 1,165 miles in 96 days. He was delayed 40 days in a season of 199 days, 18 of them by sickness.

Mr. C. D. Potter, Asst. Surveyor 3rd Grade.

(34.) Mr. Potter performed the task I gave him moderately well. He built 5 and finally closed 9 platform stations (50 days' work) ascending 15 hills over 1,200 feet high and marched 1,068 miles in 86 days, being delayed 32 days out of 179 in the field. He also observed some secondary angles with a 7-inch theodolite at a few stations.

His progress was not rapid, and I had occasion to find fault with the insufficiency of foundation given to one or two of the stations which he built, also for the most surprising error of embedding a permanent (⊙) station mark, on one side of, instead of precisely plumbed underneath, a pole and brush signal that had been previously erected and observed, which he found inconvenient or inadvisable to remove. I need scarcely say that I ordered him to revisit the spot and place the mark-stone correctly.

Mr. E. W. Laseron, Asst. Surveyor 3rd Grade.

(35.) Mr. Laseron has done a very good season's work. He accompanied the main party for 5 months and performed the duties of observatory recorder and office assistant with his usual ability, neatness and regularity, to my entire satisfaction, and that of Lieutenant McCullagh who reports most favourably of him.

The principal angle books were kept up in duplicate, notwithstanding the rapidity of the observations when there were two observers.

After the completion of the principal triangulation, I directed him to execute some minor triangulation with the 7-inch theodolite to fix some secondary points where they appeared to be most required. This he appears to have done very well, having observed 12 measures each of 55 angles at 13 stations, forming 18 triangles with a mean triangular error of 4″·6, and fixing 9 new points, with vertical angles to each, in two months, during which he marched 345 miles in 30 days, ascending 9 hills, each about 1,100 feet high and returned to Bangalor on the 30th May.

I am very well pleased with Mr. Laseron's first essay in independent triangulation. He is already a good observer, and if he continues to take pains to improve, and gains a little more experience he promises to become a very superior trigonometrical surveyor.

Sickness in camp.

(36.) Although the progress of the main party was not actually stopped by sickness, yet the hospital was never empty, and not a member of the party escaped without suffering from the common bilious or jungle fever, or from the rheumatic complaints rife in the districts traversed.

The instruments in use with the party generally in good order.

(41.) I have to report that the instruments and equipment of the party generally are in serviceable order, or in course of repair to be made so.

The 24-inch theodolite.

The principal instrument, Troughton and Simms' 24-inch theodolite No. 1 (altered) is in good working order and adjustment. As the old cases and carrying apparatus were getting shaky, I have

renewed them with lighter and more convenient ones, and I am now having a new braced tripod stand made which I trust will be as steady as, and considerably lighter than, the old one.

Observatory tent gradually renewed of late and lightened.

(43.) The observatory tent has gradually been renewed, little by little, during the last few years, and very much lightened by substituting bamboos for the heavy tie and cross rods of solid squared wood.

I think that the gain in lightness of equipment has materially aided our progress, and I am striving still to reduce the weight of every thing to be carried, to a minimum.

General appearance of the country.

(46.) The country traversed by the Series this season is one of great beauty and interest. Superficially it consists of forest clad hills and valleys of no great height or depth, diversified by open grassy glades and downs, many streams and rivers, with some prominent peaks, and many bold bluffs and precipitous cliffs.

The ridge of the Western Ghát.

(47.) The prime feature of the country is the irregular ridge line of the Western Ghâts running generally N. N. W. and S. S. E., at a distance of 10 to 30 miles from the western coast, between 15° and 13° North Latitude, and rising from a height of 1,500 feet in Sunda, to 3,000 feet in Manjerabad.

The Malnád.

(48.) This part of the country is called the "Malnád" (or Male-nádu) "Rain district" from the excessive amount of rain which falls here. On the western slopes and summits of the Ghâts, (by Ghâts is usually intended the *hills* as well as the actual *passes* and valleys between them) the rain-fall from May to October is very heavy, from 150 to perhaps 300 inches or more, falling in a single season, and this combined with frequent dense fogs and clouds, when there is no rain, night and morning, and also with the moisture wafted in from the west by the sea breeze during the hot months of February to May, produces and reproduces such a vigorous growth of plants and trees that the people can hardly keep their clearings free from jungle.

Heavy rain-fall.

Features of the Malnád.

(49.) The head of the Naggar Malnád may be considered to be the Koté Kán or Kudure-Mukh and the Balúl Rayana Duruga; or perhaps, the parallel range of high hills a few miles to the northward running from the Varáha Parvata at Ganga Mulla near the edge or ridge of the Western Ghâts where the Tunga and Bhadra rivers rise, eastward by the great Vedachala and Angrikal hills to the grand conical peak of Mérti Parvata (the "Calasa Peak" of Indian Atlas sheet No. 43.)

The drainage generally to the North and N. E.

(50.) The valleys here are from 2,500 to 3,000 feet above the sea, but fall rapidly towards the north and north-east to 2,000 feet, beyond which their slopes are more gentle and undulating, but with a decided northward and north-eastward tendency.

The Bhadra, Tunga, Choradi and Warda (Varada) all flow in this direction.

Drainage of the Naggar basin alone by the Sheravati to the N. W. The Gérsappa or Kurkanni watorfalls.

(51.) But the Shéravati which rises in the rocky fastness of Kauli Duruga, and drains the Bidárúr (vulg. Bedenore) or Naggar basin, after a north-westerly course of about 40 miles, precipitates its waters by a single drop of more than 800 feet at Kúrkanni into the Gérsappa valley or ravine, and so to the west coast. Some officers of the Indian Navy, &c., measured the main fall from a cradle suspended in front of it from a cable stretched across the chasm. They found the pool at the base of the Rája fall 829 feet below its summit and 132 feet deep. The river here is perhaps some 400 yards wide, but the main cataract falls in a narrow chasm at the north or right bank of the river only 40 or 50 yards wide. There are 3 other very beautiful cascades, but their fall is broken by projecting rocks.

The western face of the Ghâts very steep or precipitous.

(52.) The declivities on the western face of the range from Kudure Mukh to Gersappa are very steep and frequently precipitous, so much so that I suppose they very commonly attain a gradient of 30°, *i.e.*, a fall of 1 in 2, the height being half the actual base.

The peaks of the Ghâts.

(53.) Numerous peaks rise above the average height of the range by 500 to 1,000 feet, but few of them exceed 3,600 feet above the sea; Chandraguti (2,794) Kodachádri (4,411), and Kudure Mukh (6,215) feet stand out very conspicuously above all the rest, only equalled by Merti in the Tunga Bhadra Doáb, and only surpassed by the Chandra-drona (Moon [*i.e.* crescent] shaped) hills, also now commonly called the Bába Budan hills from the name of a Muhommedan Pír or

Kallandar who lived and died there some years ago, and is reported to have introduced the coffee plant first into Maisúr.

(54.) The ghâts, or passes themselves, running east and west through the range, are numerous, being on the average only 10 miles apart, and though mostly disused and impracticable now, attest the fact that there was formerly much traffic between Maisúr and the west coast. The existing traffic is large, and is maintained by means of 4 or 5 new ghâts, most of which are open and some of them already available for wheel carriage.

The numerous old passes superseded by a few new roads.

(55.) In point of fact however, trade is chiefly effected by pack cattle, some thousands of which daily throng the passes and their approaches throughout December, January and February, carrying rice, betel-nuts, pepper, cardamoms, sandalwood and other exports to the coast, to exchange for salt and manufactured goods. Many Lambânies, (or Banjâries), besides numbers of country folk from the eastward, are employed as drovers, and it is probably by these and by the Koramârs, Kerachârs and other gipsy tribes infesting the country in the dry season, that robberies are committed. Our camp was robbed four or five times without the thieves being discovered.

Traffic by means of pack cattle.

Gipsy drovers.

(56.) The population of the Nagar Malnâd appears to have diminished greatly from what it must have been at some time.

Diminished population.

The large towns which once existed, and particularly the city of Nagar, named Haidar Nagar by Haidar Ali, instead of its older name Bidarur (Bamboo-town), as the Kelladi Nayak called Bidar-halli (Bamboo village) when they made it their capital, are almost deserted, and from the frequency of the deserted rice fields we observed, the rural population has also probably decreased in recent times.

Deserted towns and rice fields.

(57.) I find more difficulty in conceiving how a large town and agricultural population ever existed in the Malnâd, than how it has decreased to its present state. The Râjas and Pâligârs or feudal and predatory chiefs having disappeared, the merchants and artisans disappeared with them, and are only to be found in places where they can practise their craft under the protection and by the aid of a strong governing power. With these classes too the agricultural population also decreased for want of encouragement, and under stress of a difficult country and an unfavourable climate. Formerly no doubt the great attraction here lay in the fact that the rulers of the country spent their revenue here.

The seat of government removed the chief cause.

(58.) The more recently deserted rice fields noticed, indicate a further decrease in the rural population, which may be largely due to the decline of slavery or rather of domestic serfdom, which was once general in this part of the country (the Malnâd), but is now disappearing.

The deserted rice fields partly due to decline of serfdom.

(59.) It is supposed that the introduction of Coffee has been one cause of the decline of serfdom. The coffee planters require labourers and offer high wages for them, and in order to obtain them, pay largely *in advance*, a temptation that serfs, who had been accustomed to receive their food and clothing &c. in kind, were unable to withstand, and therefore left their old masters for the coffee plantations.

Also to the absorption of all spare labor by the coffee plantations.

(60.) In recent times also the native merchants have "sold up" the old landholders, or supplanted many of them in their valuable areca (Kanarese *Adiké*) or betel-nut palm, pepper, and cardamom gardens, or have opened fresh gardens and coffee plantations for which they must have labourers. Like the European coffee planters before mentioned, they too pay high wages (3 or 4 annas a day for a continuance, and perhaps twice as much on occasions), and both alike, after absorbing all the labouring population of the country, obtain coolies in gangs from the South Kanara lowlands by means of large advances made to the village headmen, many of whom are large creditors and send those indebted to them up to the coffee estates and gardens to work off their debt by manual labour, (receiving their daily food only from the planters) during the open months December to March or April, after which time the coolies return regularly for the rainy season (May to October) to their homes in the lowlands.

Labourers obtained in gangs from the lowlands of South Kanara.

(61.) In this way I suppose a habit of migration is being established amongst a large class of the population, and the result to us is that no coolies, or day labourers, are to be had in the district of palm gardens and coffee estates, except from the old landholders, "Gauda" or "Heggade" (the latter are Jain) village headmen, and they have already too few domestics to cultivate all their own fields, and are unwilling to allow them to work elsewhere.

(68.) All who can, quit the Malnâd when, or rather before, the rainy season begins, except jungle fowl, bison and elephants, who roam at leisure during the rains, retiring to the

fastnesses and thickets of the ghâts and the tarai, when the weather clears and the human population returns.

Period of the bamboo.

(69.) I should not omit to mention that during the last few seasons we have witnessed the apparently simultaneous seeding and death of the bamboo.

I believe I noticed cases of the bamboo flowering and dying in small patches in 1865-66 in Bangalor and the Eastern Ghâts, and ever since that time I have yearly observed large tracts of bamboo forest simultaneously seeding or dying.

This year in the Nagar Malnád I observed very few patches of bamboo forest still alive, except in a few spots, particularly on the banks of the Bhadra River and to the west or northwest of the Bába Budan hills where we met with young bamboos of several years growth.

Mr. H. Stokes in his report on the Nagar Division of Maisúr, dated May 1838, para: 36, gives 12 years as the time for small bamboo to come to maturity and 40 years for the large kind, and he states that the small kind seeded in the beginning of 1837 round the Bába Budan hills. At Hebbe, the N.W. point of these hills, we found a very dense growth of green bamboos of the small kind, about 2 inches in diameter and 10 to 20 feet in height. These did not appear to be at all near their maturity and therefore their period cannot be one of twelve years. I have been able to get no precise information on the subject. The common belief here is that the period of the large bamboo is about 60 years and that of a smaller kind about 40.

The bamboo harvest (the seed being called "bidararisi" *i.e.* bamboo rice) is said to occur in in a year of scarcity. But the harvest is not simultaneous throughout the country; it takes several years for all the tracts of bamboo forest in a large province to seed, so that I suppose it may be only that an unusually hot, dry or peculiar season is required, after the bamboo has arrived at or near its maturity, to bring on and determine the time of its seed-bearing. The interesting fact is, that all the bamboos in the same tract, forest or patch, seed and die together, whilst those in the adjoining district seed and die together a year or two sooner or later, as if following the period of a Meteorological cycle, slightly modified by special local conditions, more or less favorable to them.

Extract from the Narrative Report—dated 1st September 1873—of Captain T. T. CARTER, R.E., Deputy Superintendent 2nd Grade, in charge Brahmaputra Series.

(2.) The principal observations in connection with the Brahmaputra Series had been stopped since the field season of 1869-70; Major Montgomerie R.E., the Officiating Superintendent decided that rather than leave these observations in abeyance for another year (when the services of one or two parties employed in principal triangulation would be available) the work should be carried on by the civil and native establishments of the No. 3 Extra or Leveling Party, in conjunction with the native establishment of the Brahmaputra Series, to which latter party Mr. H. Healy, Assistant Surveyor 4th Grade, was transferred from the Sambalpur Series.

Anticipated difficulties.

(4.) In addition to the disadvantage of carrying on the work with an establishment that had been employed for years back on leveling operations and therefore unaccustomed to purely trigonometrical work, the principal observations had been in abeyance since the field season of 1869-70, and meanwhile the position of one at least of the pillars already built had been reported critical owing to the encroachments of the Jamúna (Brahmaputra) River; besides which the rays previously cleared would naturally have become overgrown after a period of three years, especially in a climate like Lower Bengal where the growth of vegetation is very rapid; these difficulties, anticipated on taking the field, turned out unfortunately too true.

Missing tower on side of continuation.

On my arrival at Serájganj (where the party disembarked from the river steamer) I was informed by Mr. Donnelly who had preceded me with the main camp and native establishment, that the pillar at Parkoksa had been washed away during the previous rains. It was necessary at once to make arrangements to rebuild the pillar at Parkoksa on one of the old rays. A portion of the native establishment was set to work to make the necessary bricks for the new pillar, and Mr. Donnelly was deputed to superintend them, while I proceeded to Soilabari T. S. to erect the scaffolding for the observatory tent at that station which I was desirous of having done under my own superintendence, in order that the several assistants having seen one built, might be independent when employed on this work in future.

The scaffolding at Soilabari was completed on the 26th November, when I proceeded to Parkoksa to choose a site for the new pillar, ascertain what progress was being made as regards

the making of the bricks and see that no difficulties were likely to arise as would cause a delay in the speedy completion of the pillar. Leaving Mr. Donnelly to build the same, lay off new rays to such of the stations it was necessary to observe from, to fix the new station, and to build the necessary scaffoldings for observing therefrom, I left him on the 30th of November and proceeded to build the scaffolding at Rashidpur T.S. and then commence final observations at that station. On the same date Mr. Healy was deputed to proceed to four of the tower stations in advance, and build the necessary scaffoldings for observing from the same; the building of the scaffoldings at the remaining four tower stations, likely to be observed from during the season, being entrusted to Sub-Surveyor Narsing Dás.

(5.) Observations were taken at three stations as per margin, when I proposed returning to observe from the stations necessary to complete the Basalia and Bágmára polygons, in both of which the new station of Parkoksa entered. On the 29th of December I received a letter from Mr. Donnelly reporting that the Parkoksa pillar having reached the height of 25 feet had fallen down, severely injuring two of the masons: I at once proceeded by boat down the river to make a personal inquiry into the cause, which was that the bricks were moulded out of very bad clay and not half burnt; the officer in charge of the construction was Mr. A. W. Donnelly. This second mishap to the Parkoksa pillar necessitated my changing the order of observations; the stations of the Basalia polygon and four of the Bágmára polygon, being all dependent on Parkoksa. Returning to Gaborgrám T.S. and completing observations there, they were continued at the stations as per margin. On the 18th of January the pillar at Parkoksa was reported completed, and by the 5th of February Mr. Donnelly had finished the building of the scaffoldings at the stations of Poelsa, Basalia, Aloakandi and Parkoksa and had cleared the rays to the new pillar at Parkoksa. By this date both Mr. Healy and Narsing Dás had completed the building of the scaffoldings told off to them, I was therefore independent of all my assistants, as far as my observations went, and their services were available for the approximate work and minor triangulation. After Bágmára, the final observations were continued in the order shewn, up to the 21st of April, when the work was closed for the season. A slight hitch occurred at the station of Soilabári T.S: on the lamp-man proceeding there to shew his signal, he found he could not plumb the old mark, the pillar having deflected: this difficulty was got over by inserting two new mark-stones, or rather, mark-bricks, leaving the original mark-stones (inserted by Captain Thuillier) undisturbed: this necessitated my observing from Mokimpur T.S. I had been anxious throughout the season to complete the principal work up to the side Kanchipára T.S. to Garopára II.S., as the pillar at Halkachar is within ¼ of a mile of the river, and to have observed from the two stations above named would have made the next season's work independent of it; but by the 21st of April (after nearly six months incessant work) the whole of the party were more or less indisposed. At the Hill Station of Garopára, two of the signallers had to return on account of fever, water there was scarce, and I was unwilling to run the risk of laying up the establishment at the end of the field season, especially, as they had been hard at work from the beginning of November: I determined therefore to close work for the season at Jánkipur T.S.

Final Observation

Rashidpur,	December	10th to 16th.
Poorbári,	„	17th to 24th.
Gaborgrám	„	25th to 5th January.

The Parkoksa Pillar falls down at height of 25 feet.

Boladanga T.S.,	January	6th to 14th.
Sádipati T.S.,	„	15th to 22nd.
Char-Sherpur T.S.,	„	23rd to 28th.
Bágmára T.S.,	„	30th to February 7th.

Poelsa T.S.	February	8th to 14th
Basalia T.S.	„	15th to 24th
Soilabári T.S.	„	25th to 28th
Mokimpur T.S.	March	3rd to 4th
Parkoksa T.S.	„	6th to 11th
Aloakandi T.S.	„	12th to 20th
Bonarpára T.S.	„	22nd to 28th
Halkachar T.S.	„	29th to 14th April
Jánkipur T.S.	April	15th to 21st

From the time the party took the field (15th November 1872) up to within a few days of its closing work (21st April), with the exception of half an hour's rain on the 2nd February and on the 4th March, there was no rain. Captain Thuillier in his report of his operations during the field season 1869-70, describes exactly the difficulties under which the observer labours while at work in these parts, and owing to the want of rain this season, the atmosphere was particularly bad. During the month of December and up to the end of February, a thick fog covers the whole country, clearing away about 10 A.M., so that no morning angles are obtainable. At sundown during these months, the inhabitants drive in their cattle and at once set fire to the heap of refuse lying near the cattle shed. Every village is soon enveloped in smoke, and as our rays always pass over three or four villages, observations to lamps at this time of the year are impossible. As the season advances, *viz.*, from the middle of February to the end of March, the people (preparatory to tilling the land for the rain crop) burn the grass on the chars (low lands bordering the river) and the rice stubble which is left standing in the fields, leaving a heavy, smoky atmosphere which makes lamps invisible, and very often, in the case of the burning grass crossing the ray, interferes with observations to afternoon heliotropes. April is not much better; then a strong wind blows, raising the sand on the banks of the river and making it very difficult to see the heliotropes when the ray crosses it. The periodical N. W. storms begin about the 1st

Weather and atmosphere.

week of April; they come on very suddenly, and though they only last a short time, perhaps 1½ hours, it often happens, if at night, that one or two of the lamp-men have been obliged to remove their lamps for safety, and of course are unable to align them till next day, so that when after a storm the atmosphere is clear and lamps can be taken, observations are often interrupted by the instrument having been dismantled or a lamp removed.

Minor Triangulation.

(6.) In a country like Lower Bengal, a minor triangulation is almost impossible owing to the number of villages and exuberant vegetation necessitating the clearing of rays; indeed, it would be cheaper to fix any large town by the main triangulation and large sides. As it is one of your orders that on no account is secondary work to be neglected, it has been usual to fix the villages in close proximity to our stations by simply taking their direction from the pillar, and measuring their distance with a perambulator; in this way, a considerable number of villages (114 in all) have been fixed sufficiently near enough for geographical purposes. An attempt was made to cut in flags on large trees from the principal stations, but this entirely failed. Another way of fixing secondary points is by carrying a traverse, and in this way, three paka buildings were fixed, which lay near the principal work: I was anxious to fix the large towns of Mymensing and Bograh if possible by triangulation; while observing therefore from the tower station of Poerbári, I visited the small out station of Jamálpur of the Mymensing district, and saw at once that it was feasible to carry a minor triangulation, emanating from the side Poerbari T.S. to Char-Sherpur T.S. along both banks of the old bed of the Brahmaputra river, which though now a comparatively small stream as compared to the Jamúna river, is still called the Brahmaputra: the jail at Jamálpur was conveniently situated for breaking down the side Poerbari T.S. to Char-Sherpur T.S. I accordingly, on the 7th of February, directed Mr. Donnelly to take up this work, and it occupied him for the rest of the season *viz.*, to the 19th of April. I am bound to state that I consider that this was very trying work, and Mr. Donnelly deserves great credit for carrying it through successfully during the months of March and April, the hottest time of the year in these parts; Mr. Donnelly at the close of his labours was much pulled down: his total out-turn of work was as follows:—

Mr. Donnelly takes up the Minor Triangulation to Mymensing.

Number of stations observed from		54
Do. of triangles of which 3 angles were observed		54
Do. of intersected points		13
Do. of miles of ray tracing		8
Do. of points fixed by ray traverse		5
Do. of heights observed		1
Do. of paka points fixed		21
Do. of paka platforms built and fixed		4
Length of secondary series	miles	44
Area of secondary triangulation	square miles	32

In addition to this, he had previously completed 34 miles of ray tracing to and from the Parkoksa pillar, and superintended the construction of 5 scaffoldings for principal observations. Unfortunately his work in recess bears a very bad comparison to his field work. It was the 6th of August before his angle books were brought up and the computation of his field work could be taken in hand.

Mr. Healy, Assistant Surveyor 4th Grade.

(7.) Mr. Healy having completed the building of the four scaffoldings allotted to him on first taking the field, he was directed on 15th January to commence the building of the four pillars as per margin, necessary to complete the series on its western flank: this work he had finished by the 31st March, when he rejoined my camp and was subsequently employed in recording, bringing up angle books, &c. I have not had an opportunity of visiting any of the pillars built under Mr. Healy's direction, but I have every reason to believe that he has exercised a careful supervision in their construction: his monthly papers, accounts &c., have been well and neatly sent in, and in office he has worked hard.

Approximate work.

Kúshdoho T.S.
Narsingbanj T.S.
Gobindpur T.S.
Alangjáni T.S.

Narsing Dás, Sub-Surveyor.

(8.) About the time Mr. Healy was directed to complete the building of the remaining pillars (tower stations) of the series, Sub-Surveyor Narsing Dás was deputed to build the platform stations on the eastern flank in the Kurabári Hills, the western spurs of the Garo Hills; this piece of work he also completed, under difficulties, by the 31st of March. The majority of his establishment were laid up with fever the greater part of the time, this part of the country being very unhealthy and water scarce. Before entering into these parts, I had secured the assistance of the Deputy Commissioner at Táro (Gáro Hills) and had also procured parwanas from the Assistant Commissioner of Goalpára. Narsing Dás met with no difficulties excepting those due

to the unhealthiness of the country; he found the inhabitants only too willing to assist in road making, bringing up water &c. I consider that great credit is due to Narsing Dás for successfully completing the building of these platform stations by the above date when he rejoined my camp. He has been of the greatest assistance to me in every way both in the office and the field.

Amjad Ali, Sub-Surveyor.

The other Sub-Surveyor Amjad Ali acted as my recorder during the whole of the season as well as assisting in the current office work.

Mr. C. J. Neuville, Surveyor 2nd Grade.

(9.) Mr. Neuville took no part in the field operations during the season having been granted six months leave on medical certificate from the 1st November 1872 to 1st May 1873. Since the return of the party to recess quarters he has worked hard at the various computations and given me satisfaction.

People and country.

(10.) On both sides of the Jamúna (Brahmaputra) river and bordering the same, the population is entirely Muhammadan the people appear industrious and well behaved, with large herds of cattle, good crops and comfortable villages, they seem to live an easy, independent life. The men appear to be strong and healthy and those not employed in agriculture are boatmen. Hâts or fairs are held at all the large villages some day in the week. The constant occurrence of fires in the villages must however be a source of anxiety, more as regards the loss of grain &c. stored in and around their huts, than the loss of the latter themselves, which being composed of grass and bamboos are easily replaced as both are plentiful. A mud hut is never seen, the reason being that walls built of mud or of unburnt bricks would be washed away during the heavy rains. In most of the large zamindári holdings there is one paka building called the zamindár's kachahri. The chars (name given to the ground on the banks of the river left dry as the river recedes after the rains) produce the best crops, one of the chief being jute which is grown to a great extent in the three districts of Bograh, Mymensing and Rangpur, especially in the latter. Serájganj is the principal jute mart in this part of the country, and has become of such importance as to warrant the Bank of Bengal establishing a branch there; it is also the site of a very flourishing Jute Spinning Company, the mills of which employ some 800 natives daily, and children from four years old are to be seen working at the machinery as adroitly as in some Manchester Cotton Spinning Mill. The party being provided with six elephants there was no difficulty in moving about the camp equipage &c., but without this means of conveyance great difficulties would arise in moving from station to station. The country being low (not more than 50 feet above sea level) is intersected with khâls or watercourses and covered with bhíls or marshes.

Proposed employment during field season 1873-74.

(12.) There remains to complete the junction with the Assam Longitudinal Series either 3 quadrilaterals or two hexagons. In addition to completing the principal triangulation it will be necessary to protect the pillars at the hill stations as laid down in Departmental Orders. The assistant employed on the work will have ample time and opportunity for secondary triangulation and connecting with the G. T. Survey some of the stations of the Gáro Hill Topographical Survey, and such prominent peaks as may be visible from our hill stations. In the course of next season's work, I propose connecting the Civil Station of Bograh (should you think it desirable), but I am afraid it can only be done by a ray trace traverse, as even with small sides of one mile or so in length, a minor triangulation would be impossible, except at great expense, owing to the numerous villages that are studded about and the amount of vegetation necessitating the continual clearance of rays.

Considering the circumstances under which the party took the field, being all new to the country and work, with a native establishment, the signallers of which had grown rusty after a cessation from principal work for a period of three years, and a considerable delay being caused by marching and countermarching due to the fall of the pillar at Parkoksa, in addition to the invariably bad state of the atmosphere, I hope that the out-turn of work as given in the accompanying table may be considered fair.

Extract from the Narrative Report—dated 22nd August 1873—of Captain A. PULLAN, S. C., Officiating Deputy Superintendent 3rd Grade, in charge Kattywar Party.

Preparations for taking the field.

(1.) The party left recess quarters on the 10th November, the Assistants and Native Surveyors proceeding by rail to Viramgám and the native establishment, under Mr. E. Wyatt, by rail to Bombay, thence by boat to Gogo and from that port by road to Viramgám. Captain Trotter joined the Head Quarters Camp at Viramgám on the 25th of November.

Some few days were occupied in projecting points &c. on the plane tables and then the Surveyors proceeded to take up their respective plane tables.

(2.) The season 1872-73 has been a satisfactory one. 2,642 square miles have been topographically surveyed on a scale of 2 inches = 1 mile; 2,680 square miles have been covered by net-work of triangulation; 739·5 linear miles of boundary traverse have been run and every boundary pillar or stone fixed, besides 409·3 linear miles of traverse, which has been carried along the margins of plane tables to test the accuracy of the detail work.

Out-turn of work.

(3.) The portion of the province under survey, during the past season, was the northern portion of Jhálawár, a bare and sterile country bordered on the north by the wide salt wastes of the Rann of Kutch; the detail surveyors met with no obstacles to hinder the rapid execution of their work and thus a very considerable area of ground was topographically surveyed this year.

(4.) Captain Trotter having been selected to accompany the British mission to Yárkand, I proceeded by order from Head Quarters to relieve that Officer at Wadwán, and took over charge of the Kattywar Party on the 6th of April, and from that day until the 28th April I remained at Wadwán conducting the current work of the office and bringing up some arrears of work. Finding that many alterations had been made in Wadwán Camp, more especially the extension of the Railway Line to the camp and the erection of several blocks of building in connection therewith, I made a re-survey of the portion of ground in question, and added the details, when complete, to Sheet 12 of Kattywar, which had already been published. I also went over all the published sheets of Kattywar, making such small corrections and addenda as were necessary previous to despatching the maps to office of the Political Agent, Rájkot, for sale.

Captain Trotter, R.E.

(5.) On the 28th of April all the topographical Surveyors having completed their work, I started for recess quarters and opened office at Púna on the 1st of May.

Return to recess quarters.

(6.) Mr. McGill, on arrival at Viramgám on the 15th November, was employed in preparing a chart of the triangles to be broken up by the net-work triangulation which he was about to take up; on the 3rd December he began work at Rájkot and carried a net-work of triangulation over Sheets 34 and 35, completing 1,400 square miles by the 26th of March on which date he closed work.

Mr. McGill is so well known as a rapid and excellent observer, and his work is always so good that it is unnecessary for me to comment further upon it.

John McGill Esq., Assistant Supdt. 1st Grade.

(7.) Mr. Ryall began work on the 28th November and continued sketching ground throughout the field season. He closed work on the 10th of April, having completed 194 square miles of survey. Mr. Ryall works slowly but accurately.

Mr. F. Ryall, Surveyor 4th Grade.

(8.) Mr. Wood was employed during the early part of the field season in projecting plane tables. He commenced plane tabling on the 20th December and worked until the 18th January. He was then summoned to Dhrángdra where he remained computing until 21st February. He again took up topographical work on 22nd February and closed work finally on the 6th April, having completed 164 square miles of topography.

Mr. Wood is a very valuable assistant as well in recess quarters as in the field.

Mr. J. Wood, Surveyor 4th Grade.

(9.) Mr. Gwynne on arrival at Viramgám was employed in completing fair Sheets 23, 24 and 29, and in mounting and projecting plane tables until the 16th of December, on the 18th he commenced plane tabling and closed work on the 5th April, having completed 239 square miles of topography in very good style, besides superintending and examining the work of Sub-Surveyors Govindji Mahalay and Nilkant Vittal. Mr. Gwynne is a most valuable assistant both in the field and in quarters, and his work this season is as thoroughly satisfactory as that of previous years.

Mr. N. C. Gwynne, Asst. Surveyor 1st Grade.

(10.) Mr. Rendell was employed on his arrival at Viramgám in allotting work to the various traverse Surveyors. On the 24th of December he commenced plane tabling near Pátri, and turned out 192 square miles of accurate and neatly executed work by the 20th of March. On the 23rd March Mr. Rendell relieved Mr. McGill who was proceeding on leave, and took up the net-work triangulation in Sheet 33. This work Mr. Rendell completed on the 20th of April, having triangulated 270 square miles of country, altogether a highly satisfactory out-turn for the season.

Mr. T. Rendell, Asst. Surveyor 1st Grade.

Mr. E. N. Wyatt, Assistant Surveyor 2nd Grade.

(11.) On the 28th of November, Mr. Wyatt commenced work and proceeded to triangulate Sheets 10 and 10—a of Kattywar. On the 16th December he joined Mr. Rendell and computed points for the R. Plane Table N.E. Section of Sheet 10. He triangulated again from 20th December to 15th January, sketched ground in Sheet 10 from 28th January to 28th February, commenced the triangulation of Sheet 32 on the 11th March and completed it on the 21st April. Completing in all 1,010 square miles of net-work triangulation and 100 square miles of plane table sketching.

Before leaving for Masúri, Captain Trotter expressed himself much pleased with Mr. Wyatt's energy and steady hardworking qualities.

Mr.W. A Fielding, Assistant Surveyor 3rd Grade.

(12.) Mr. Fielding commenced work at Viramgám on the 17th November and was employed in preparing plane tables and completing the fair maps of Sheets 23, 24 and 29. On the 1st of January he began topographical work and finished on the 2nd of April as he was suffering a great deal from exposure to the sun. Mr. Fielding completed in all 283 square miles of plane table sketching of good quality and execution.

Visaji Punt, Senior Native Surveyor.

(13.) Visaji Punt was employed throughout the field season with the Head Quarters Camp and was extremely useful. In April he proceeded by my orders to the Rann and took levels at a mile apart along the edge of the Rann as it passes through Sheets 10 and 20.

This piece of work extremely irksome on account of the great heat and want of water, he completed entirely to my satisfaction. He rejoined me at Wadwán on the 24th of April.

Govindji Mahalay, Sub-Surveyor.

(14.) Govindji Mahalay was employed during the season in plane table sketching. His work is favorably reported on by Mr. Gwynne as far as regards Sheet 22, but I find the drawing of the low ridges and scattered brushwood jungle in Sheet 20 is much exaggerated, and calculated to convey a wrong impression of the ground.

Vishnu Moreshwar, Sub-Surveyor.

(15.) Vishnu Moreshwar was employed on topographical work during the season. Mr. Fielding reports favorably as to the quality of this Sub-Surveyor's work, but adds that he found him inclined to take his work somewhat too easily.

Keshu Vittal, Sub-Surveyor.

(16.) Keshu Vittal was employed during the entire season as recorder to Messrs. McGill and Rendell.

Narsu Dinkar, Bholuji Bhosekar, Krishna Govind, Tukaram, Sub-Surveyors.

(17.) These four Sub-Surveyors were employed in running boundary and check traverses during the field season. The results of their respective work will be found in the tabular statement.

Shridhar Succaram and Nilkant Vittal, Sub-Surveyors.

(18.) Shridhar Succaram and Nilkant Vittal were employed on topography throughout the season, both turned out good work and are favorably reported on by Mr. Gwynne.

(19.) Having only taken over charge of this party at the termination of the field season, I am unable to do more than give the short outline sketch which I have given of the proceedings of the party during the field season. Captain Trotter before leaving expressed himself pleased with the work of all hands, and on careful comparison of the junctions of plane tables and the agreement of traverse check lines with the detail drawing, having in view also the average triangular error of the triangulation and the average linear and circuit errors of the traverses, I most readily endorse Captain Trotter's opinion of last season's work.

Arrangements for next season's operations.

(20.) The work which I have laid out for the coming season is as follows :—

1st. The net-work triangulation of Sheets 43,44,45.

2nd. The furnishing of extra points in Sheet 40 and the survey topographically of Sheets 40,41 to complete Degree Sheet XI.

3rd. The Survey topographically of Sheets 31,32,33,34,35 on a scale of 2 inches to 1 mile.

4th. The survey of the Cantonments, Civil Station and native town of Rájkot on a scale of 12 inches to 1 mile agreeably to the instructions contained in your letter $\frac{49}{953}$, dated 4th August 1873. Owing to the complicated nature of the state boundaries near Rájkot and intricate and hilly country comprised in the 5 sheets to be surveyed topographically, it may not be possible to complete the plane table sketching of the whole 5 sheets, but every endeavor will be made to do so.

TABULAR STATEMENT OF OUT-TURN OF WORK IN KATTYWAR DURING THE FIELD SEASON 1872-73.

Triangulation.

No.	Observers' Names.	Instrument used.	Area triangulated in square miles.	No. of Points Heights fixed.	No. of Points Position fixed.	No. of stations visited.	Triangles, 3 Angles observed.			Triangles, 2 Angles observed.	
							No. of triangles.	Mean triangular error.	Discrepancy per mile.	No. of triangles.	Average discrepancy per mile.
								"	Feet.		Feet.
1	J. McGill, Esq., ...	Cooke and Son's 7-inch ...	1400	244	653	69	125	8·1	0·6	1051	1·8
2	Mr. T. H. Rendell, ...	„ „ ...	270	21	123	16	29	16·1	0·7	186	2·2
3	„ E. N. Wyatt, ...	Troughton & Simms' 6-inch	1010	93	313	59	90	17·2	0·4	566	1·9
		Total	2680	358	1089	144	244	Mean 13·8	Mean 0·6	1803	Mean 2·0

Topography.

No.	Plane Tablers.	Area surveyed Scale 2 inches = 1 mile.	Average No. of plane table stations per mile.	Remarks.
1	Mr. F. Ryall, ...	194	7·7	
2	„ J. Wood, ...	164	7·3	
3	„ N. C. Gwynne, ...	239	6·1	
4	„ T. H. Rendell, ...	192	5·6	
5	„ E. N. Wyatt, ...	100	4·3	
6	„ W. A. Fielding, ...	283	5·0	
	Native Surveyors.			
7	Govindji Mahalay, ...	360	7·0	
8	Vishnu Moreshwar, ...	336	5·9	
9	Shridhar Sucaram, ...	452	6·6	
10	Nilkant Vittal	322	6·5	
	Total	2612	6·2	

Traverses.

Names.	No. of Linear Miles traversed.		Average error per 1000 links.	Remarks.
	Táluka Boundary.	Check Lines.		
Narsu Dinkar, ...	207	161	0·89	
Krishna Govind, ...	252	11	1·17	
Bholuji Bhosekar	280	52	1·05	
Tukaram Chowdry	0	185		
	739	409	1·04	

Extract from memoranda forwarded by Captain Trotter, R.E.—late in charge Kattywar Party—on the operations during Field Season 1872-73.

Captain Pullan's report.

(1.) As Captain Pullan took charge of the party before the close of the field season and has had an opportunity of carefully inspecting and examining the whole of the work, I leave to him the duty of reporting on the amount and quality of the work performed by each individual as well as of the cost of the survey and other details usually contained in the General Report.

Aspect of the country.

(2.) The country surveyed has been as usual in Kattywar of a very varied character; adjoining a large flat tract of salt waste, the surveyor comes upon rich, well cultivated soil, bounded perhaps on the other side by two ridges of sandstone absolutely devoid of vegetation. The whole of the eastern portion of the ground is decidedly flat with hardly a rise of any description. Near Dhrángdra however, and running down N.N.W. and S.W. from it, are numerous sandstone ridges many of them valuable as quarries. The sandstones of Dhrángdra being famous in Guzerat, and the Dhrángdra "Chakis," or round mill-stones, common throughout the country.

Towards the south-west of the ground surveyed, the nature of the country changes: there hills and jungle take the place of plains and cultivation. The produce of the country is much the same as detailed in former reports: wheat, bájra, cotton, jawári and til being the chief productions. Unlike the other parts of Kattywar, which have been surveyed, almost the whole of the water supply is here procured from tanks. Where there are streams, the water is generally brackish, and the inhabitants always drink in preference from the tanks of which there are generally one or more to every village. These mostly dry up in the hot weather; but in the majority of them there are paka wells, from which water is procured when the tank is itself dry. Many of the large tanks in cold weather present a very picturesque appearance with the tops of half a dozen or more wells appearing just above the surface of the water.

Large underground wells or "Báolis."

(3.) A peculiar feature of the country is the number of large paka wells or "báolis" generally built some hundreds of years ago in the vicinity of what were then large and populous towns. Some of them are very roomy and beautiful, the covering and the ornamentation of the approaches being very elegant and elaborate. A broad flight of steps generally richly ornamented at the sides, leads down to the water. On the first landing place you look through a long vista of 3 or 4 cupolas, on descending a few more steps to a lower landing, you again look along and through parallel rows of cupolas, and on getting to the bottom, and near the level of the water, you look through a third row forming a basement of very elegant triple-storied cupolas. These are erected over each of the 3 or 4 wells at the bottom, the whole are surrounded by a stone pathway by which you can get access to the smaller wells and to a large open circular well at the other end, from which water can be lifted to the top by the usual methods without the trouble of descending the steps. The temperature at the lower landing of these wells is cool and delightful, and would form a charming place in which to spend the heat of the day in the hot weather. It is a peculiarity of these "báolis" that there is nothing above ground to lead to the supposition that there is any thing unusual underneath, a long low stone wall, 2 feet in height, being all that is visible to the eye.

Description of the Rann of Kutch.

(4.) With the exception of a few antiquarian remains, the country is most uninteresting, no mountains or even hills worthy of the name, no fine rivers, or large forests, or picturesque views meet the eye. Towards the north a partially cultivated, treeless plain is all that the traveller sees, with an occasional tank whose low banks form the only practicable points on which to erect stations for our triangulation. This plain gradually merges into the Rann of Kutch, an extensive desert about which much has been written by various authors but of which a short description will not be out of place here.

It is a vast and perfectly flat tract of desert without a scrap of vegetation of any kind and so little lower in level than the country to its south that in many places it is impossible to say where the Rann begins and the mainland ceases. There is often however, an intermediate strip of land, between the cultivation and the desert, on which grows a short stunted grass, the food of the cattle and wild asses when they can get nothing better. On the other hand portions of the Rann extend inland in bays meeting the sandy beds of rivers which all sink and are lost in the sands as soon as they come in contact with the Rann.

(5.) In some few places islands rise out of the midst of it, generally shewing marks of volcanic action. Some of these islands are more or less covered with grass, to collect which carts are sent over at the proper season from the mainland. In the cold weather it is possible to traverse the Rann with impunity, as although the sun is always hot yet there is generally a cool breeze blowing up from the sea on the west; but in the hot weather I have been assured that to

spend a day on the Rann would be almost certain death: I have heard of more than one authenticated case where men have got lost on the Rann and have wandered about in a circle until they have fallen exhausted. I can quite imagine this to be true; for as the hot season advances the dazzling glare is blinding and the heat overpowering. The mirage distorts and magnifies the smallest object into the most wonderful shape; a stick appears like a tree and a stone like a hill, and no distant object can be seen at all.

(6.) The composition of the surface and subsoil appears to be in tolerably regular layers of sand and clay with a large quantity of saline matter admixed. This saline deposit attracts the moisture from the atmosphere and the surface is then frequently damp. For some months in the year, the Rann is under water. When the prevalent westerly winds begin to blow in March, the water in the Gulf of Kutch is gradually heaped up, and it advances in a slow wave right up the Rann until the fall of the monsoon in June, by which time almost the whole of the western portion is covered with water, varying from a few inches to a few feet in depth. When the rain falls, fresh water is carried into the Rann by the rivers that empty themselves into it and the whole becomes a vast lake—nowhere more than a few feet in depth—and which subsides gradually at the close of the monsoon. The admixture of fresh and salt water kills large numbers of fish; and, I have, in crossing the Rann, come across the remains of myriads of prawns which appear to have met their death in this manner. I have, also in the cold weather, seen heaps of dead locusts, which fortunately for the inhabitants of Kattywar, have fallen victims to exhaustion in crossing this desert tract.

(7.) The only animals that live in this wilderness are the common antelope, which often wander out some miles and spend some hours of the day there, and return to the mainland for food and water, and the *Ghorkar* or wild ass (Khachar is the local name). The latter breed in the Rann islands during the monsoon months, finding there plenty of grass and water: after the monsoon, when the waters have retired, they sometimes cross over to the mainland, and as the Rann is then a mass of slush several inches deep, they are sometimes driven into it by men on foot who are able to pursue and drive them about until the young ones fall perfectly exhausted and are easily captured. Few however caught in this manner survive this preliminary treatment.

(8.) The Rann is crossed by several cart tracks which will be shown in the season's maps. Some of these, towards the head of the Rann, are only closed for a few weeks in the year and are even then open for horsemen and foot passengers; others nearer the head of the Gulf are closed for half the year, *viz.*, from the first rise of the water in March or April until the subsidence of the waters after the monsoons. At the head of the Rann, and included in this season's mapping, are the new and extensive Government Salt Works at Pátri, a short account of which may not be uninteresting.

Salt Manufacture.

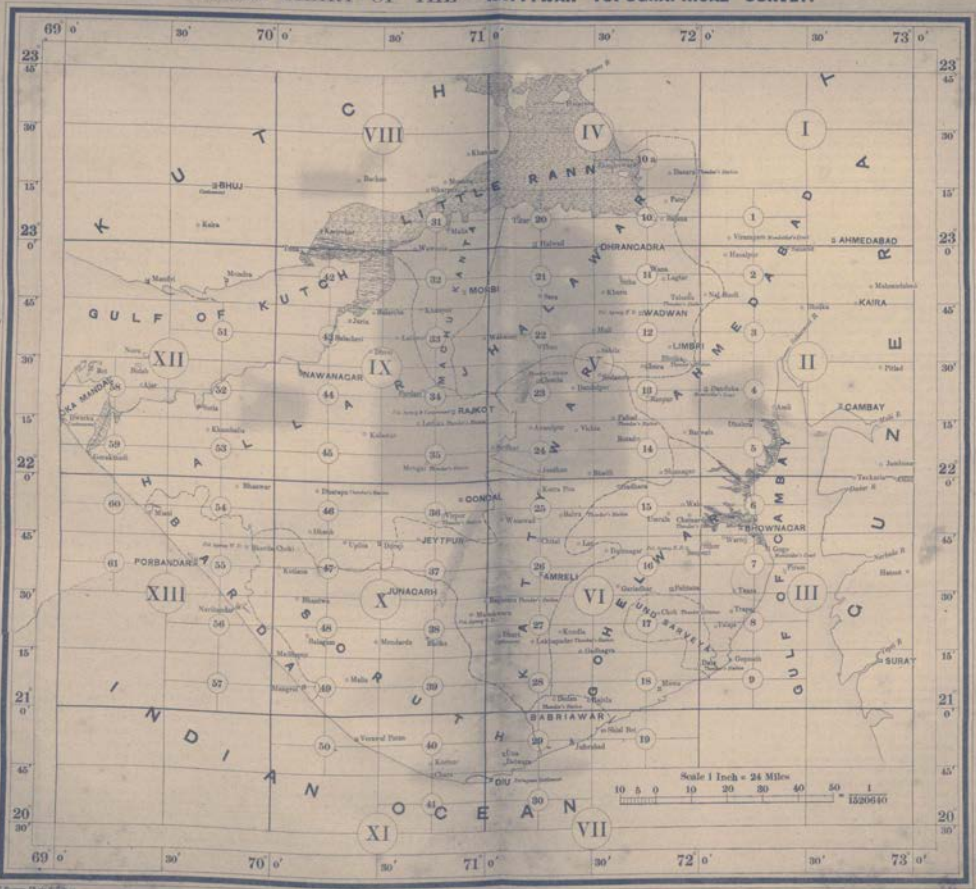
(9.) For more than a hundred years past, salt has been manufactured from water taken from wells dug in the Rann, more particularly at Kura in the Dhrángdra state and in Pátri and the neighbouring villages of Kharagora, Bajana and Uru on the eastern border of the Rann. Government has hitherto contented itself with levying a very heavy duty on all salt sold in our own districts; but on account of the large amount smuggled from Kattywar and also from the above mentioned places, Government has been compelled to undertake the manufacture itself. With this end in view, all the old Rann works have been closed (with the exception of those belonging to Dhrángdra, an independent state in Kattywar), compensation having been paid for old interests involved. All the works also on the western coast of India, between Cambay and Bombay, are tobe or have been closed, and all that part of the country will be supplied with Rann salt, manufactured at the Government Works. It is hoped by these means and by an introduction of an efficient line of patrols on the frontier, between the Kattywar states and our own districts, it may be possible both to keep the Kura salt from getting across to our own and the Gaikwar territories and at the same time to prevent the Málwa opium from getting to Kattywar.

(10.) Prior toGovernment taking over charge of the new works at Pátri, the salt was manufactured by the "Agrios" (as the makers are termed) on their own account, in quantities limited by Government, to be sold to private merchants at a maximum rate of 2 annas per maund. Practically they did not get this price for it, as the merchants who purchased generally did so (on account of the abundance of the supply) at a much lower figure. Government now employ these same "Agrios," let them dig the wells and make the pans (giving them advances for that purpose) and purchase the whole of their stock of salt (if of approved quality) at 1¼ annas per maund, all round, removing the salt to warehouses on the adjacent shores that have been constructed for the purpose. The Agrios are therefore really much better off than they were before, as formerly that portion of their stock which remained unsold before the periodical setting in of the monsoon (when the whole of the works are flooded and the wells and pans filled up) was liable to be swept away. This actually occurred the year before last to the utter ruin of the salt owners, and I am informed that 42 per cent of the entire produce of the last five years has been washed away in the same manner.

(11.) It was proposed to manufacture during the past season twelve and a half lakhs of maunds of salt, which is a little above the amount estimated as required for consumption in that

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

INDEX CHART OF THE **KATTYWAR TOPOGRAPHICAL SURVEY.**



C. Spencer Photo & Lithos.

The numerals 1, 2, 3 &c., indicate the sheets on the scale of one inch to the mile. The numerals I, II, III &c., indicate the degree sheets, on the scale of 1 inch to the mile. The two inch sheets are divided into 4 sections known as the N.E., N.W., S.E., & S.W., sections of the sheet, of these a few copies will be published on the Scale of the original Survey, &c., 2 inches to the mile for the use of local officials.

Denotes country Topographically Surveyed up to 1872-73.
Dates Triangulated to accuracy up to 1872-73.

Photozincographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Dun. November 1873.

portion of the Presidency lying between Bombay and Ahmadabad. For this purpose 252 pans, each 250 feet long by 60 feet wide, have been constructed. The process of making the salt is very simple and is almost the same at Pátri as at Kura, but at the latter place, the pans are arranged in no sort of order, being scattered in all directions all over the place; whereas at Pátri they are arranged symmetrically in rows with spaces between for storing the salt. As soon as the monsoon has come to an end and the piled up waters of the Rann have retired, each "Agrio" sets to work to dig a well and to make his pan. The well has first to be sunk, as without the water procured from it the workmen would be unable to puddle and render watertight his pan. The sinking of the well, which he accomplishes with the aid of hired labour, occupies him some weeks. He soon reaches water, it is true, but only what is termed surface water, and which does not contain nearly so much salt in solution as another kind of water which he reaches generally at a depth of from 20 to 30 feet, on reaching which there is generally a rush of very strong brine which comes up with considerable force and rises several feet in the well: when he gets this rush of water he is satisfied and commences to prepare his pan. Sometimes however instead of tapping the brine he comes to a hard red clayey soil called "morod," and the experience of the past years has shown that when he comes to this he must abandon all hope of getting to the brine and start a fresh well elsewhere. Assuming however that he has reached good water, he prepares his pan by raising a small bank of earth all round it. He then pumps up water with the common balance pole and bucket and covers his pan with it to a depth of one or two inches. This water sinks into the ground and he then commences to puddle the pan by constantly (with the aid of his hired assistants) treading the ground, a most laborious process, for the pouring on of water and treading and consolidating has to go on until the bottom of the pan becomes quite waterproof, which from the quantity of clay in the soil it ultimately does of course in some soils quicker than in others.

(12.) This preliminary of well sinking and pan preparing generally occupies about two months, when ready the brine is pumped in to a depth of several inches and left to evaporate. As soon as the greater portion of the water has done so more water is poured on, and this is repeated perhaps once in every three or four days. Crystals of salt soon form at the bottom and the Agrios have to stir these crystals about frequently and briskly with a large rake. This goes on until a crop is ready, which generally happens about the middle of February, when all the water being allowed to evaporate, the salt, which then forms a layer several inches in depth over the whole pan, is taken out and arranged in conical heaps by the side of the pan, whence under the new arrangements, instead of being left on the ground and sold as the opportunity offered, it will be immediately carried on a tramway by trucks, to the central stores, about 2½ miles off and on high ground bordering the Rann. There it will be weighed and handed over to the Government Official deputed to receive it. This central store has been connected by a branch railway line about 22 miles in length (Pátri to Viramgám), which has been specially made for the purpose, and which was in course of construction while we were surveying the ground. The salt will be carried by the Railway Company to the depôts that are to be formed at Ahmadabad, Bhroch (Broach), Baroda, Balsar and Súrat where it will be stored away and sold to the public at a fixed rate.

(13.) Instead of taking one crop in February and another in April or May, a supply of better salt is obtained by continuing the manufacture without emptying the pan until April or May. An average crop of 18 lb per superficial foot of evaporating surface may be obtained from a good crop up to the middle of February, and for the second crop a somewhat larger quantity; if the crop be taken at the end of the season, only about 34 lb of salt of a superior quality may be obtained per foot. These quantities depend very much upon the amount of brine that may be pumped up, and if a man is lazy he will get a small return. The brine also is variable in quality, and some wells will give more salt than others. In March and April the salt is apt to receive very serious injury from the clouds of dust and sand that fly about. The Dhrángdra works at Kura appear to suffer more from this cause than the more protected works at Pátri. At the former place I was told that the manufacture was generally entirely stopped from this cause and from the supply of water in the works running short about the end of March or beginning of April.

(14.) The heat in the Rann being so excessive, it has been arranged that all the labour of carriage and storeage at the Government Works shall in the hot weather be carried on at night. At Kura the salt is generally made from surface water as they cannot obtain the brine springs which afford so rich a crop at Pátri. The reason is I believe that the whole ground at Kura is underlaid with "morod" and thus the water being deficient in quality as well as in quantity, they require two wells instead of one for each large pan: the process of manufacture is the same.

(15.) I estimated, after careful inquiries and measurements, the sale of salt at Dhrángdra to be about one lakh of maunds per annum. It has however been estimated by the Customs' Collector of Bombay at as high a figure as four lakhs, of which he assumes that 3 lakhs are smuggled across our frontier, causing a loss to our income of nearly six lakhs of rupees. Although we have been in correspondence on the subject, we cannot arrive at less discordant results. The calculations are somewhat elaborate and I need not give them here, but my own figures are confirmed by the statements of the Darbár Officials who however would naturally be disposed to estimate it at as low a figure as possible; for every thing over one lakh, which has been assumed to be the probable consumption in Kattywar itself of Kura salt, must be admitted to be smuggled.

(16.) In the Kura works, the digging of the wells and making of the pans, are undertaken by and at the expense of the "Agrios" who are assisted by their families and follow no other avocation. At our own works the salt manufacturers are also cultivators. The produce is generally sold at about 12 annas the donkey load (2½ maunds), but varies to from 10 to 13 annas. According to quantity of the total amount sold, one anna in the rupee is taken when the accounts are made up (annually) to defray the expense of establishment, which is very small consisting of one kárkun, one havildár and five peons: the balance is divided between the Darbár and the Agrios. Each therefore receives say 5½ annas per donkey load or 2$\frac{1}{5}$ annas per maund clear profit to the Darbár, and profit, less working expenses, to the "Agrios." Besides this there is a small duty levied of 2 pies per donkey load, or Rs. 1-8 per cart load.

(17.) The pans vary in size from 2,500 square feet to 10,000 square feet as against a uniform size of 15,000 square feet at the Pátri works. There are 80 wells at work but in most cases two wells are required for each pan. I purchased salt, retail, in the village of Kura at 112 pounds the rupee.

(18.) I have heard it suggested that the brine at the Kura wells was supplied direct from the sea by subterranean filtration. I made some experiments in the cold weather to test the same, but could detect no positive traces of tidal influence. It is true, there were periodically diurnal rises and falls in the water of the wells, but this I clearly traced to the effect of the pumping of the water up from other wells and the consequent lowering of the level of the water in the adjacent wells. I had purposed continuing the experiments in a more careful manner in the hot weather, but was unable to carry out this idea. It was said at Pátri that the water rose much higher in the wells in the hot weather than in the cold and this would certainly indicate tidal influence, as the periodical rise of water in the Rann in that season would certainly produce that effect, did subterraneous filtration exist to the extent supposed.

(19.) On the other hand at Kura very much nearer the sea, the water in the wells is said to be very much lower in the hot weather than at any other time; but it may be said that the "morod" underlying the Kura wells would prevent the influence of the tidal wave being felt there. Mr. Maury, the Customs' Officer, in charge of the Pátri works, was interesting himself in the question and has possibly carried out further experiments.

Secular depression of the Rann.

(20.) I made constant inquiries along the edge of the Rann to indeavour to get some light thrown on the subject of the supposed secular depression of the Rann; but although the oldest inhabitants recollect on about three occasions, during the past fifty years that the waters prior to the monsoon had advanced further than usual, I could not gather that there had been any permanent change of a marked nature. There is a doubt in my mind that the Rann was once the bottom of the sea or rather of a large shallow bay. At Jhinjuwára on the east edge, about 50 years ago (as far as I could learn from native reports) a large iron anchor was undoubtedly found buried in mud. It was broken up within recent years and I was never able, although I repeatedly tried, to get hold of any man who ever saw it: I have no doubt whatever that such an anchor did exist.

Extract from the Narrative Report—dated 11th September 1873—of Major C. T. Haig, R.E., Officiating Deputy Superintendent 1st Grade, in charge of the Guzrat Survey.

(2.) We were unusually late in taking the field, for the previous field season had been unusually long, which of itself called for a long recess, but apart from this, we were detained longer still by having to take up the work of utilizing the maps of the Revenue Survey, which had well nigh been abandoned as an impracticable job, but which you decided (on your inspection of this office) should again be proceeded with. Consequently it was not till the 23rd December that I left Poona myself, having sent off my Assistants a few days previously.

(3.) Owing to our taking the field so late and to the locality of our topographical work being so flat, close and wooded, we have only completed the topography of two sheets Nos. 9 and 10 and one plane table *viz.*, No. 8 of sheet 8, comprising an aggregate area of about 1,175 * square miles; but the triangulation and traversing have been pushed on, so that we have three sheets quite ready to be topographically filled in, and two others partially ready which require only some traversing for effecting the necessary connection between the Revenue Survey marks and our stations, and besides a net-work of triangles of about 3 mile sides, extended over about three-eighths of another sheet.

* NOTE.—Exclusive of margins.

(4.) The country topographically surveyed this year includes portions of six sub-tálukas of the Kaira Collectorate, the whole of the Pitlád Mahal (pargana) of the Gaikwar's territory, and nearly the whole of the Cambay territory, and makes complete the mapping of a continuous strip of country comprising 6 sheets lying between meridians 72° 30′ and 73° and parallels 21° 30′ and 23°, reaching from the outskirts of Ahmadabad to half way between Broach and Súrat, and containing the large towns of Kaira, Mahmudabad, Matar, Nariad, Barsad, Pitlád, Cambay, Jambusar, Amod, Wagra and Hansot, and the mouths of the rivers Narbada, Dhadar and Mahi, and about 35 miles of the Sabarmati, and the same length of its tributary the Watrak, and its confluents the Meswa and the Siri, also about 30 miles of the Khari river, the waters of which lose themselves over the rice cultivation west of Kaira, and eventually drain into the Sabarmati. The whole of this country is exceedingly flat, and with the exception of the promontories between the mouths of the rivers, is finely wooded, indeed, that of the eastern halves of sheets 8, 9, 10 and 11 is so thickly covered with trees that though exceedingly pretty to the eye of the admirer of nature, it is almost appalling to that of the topographical surveyor.

(5.) Owing to Captain Pullan being taken from this Party to take charge of the Kattywar Survey, I was unable to commence any triangulation in the Dáng district which I had intended to do.

(6.) On taking the field our strength comprised as per margin, and during the season there were the following casualties :—Captain Pullan withdrawn from 1st April 1873 to take charge of the Kattywar Survey, Mr. Hickie proceeded on 6 months' sick leave from 1st March 1873 and Mr. McA'Fee temporarily laid up by sickness for nearly a month.

Major C.T. Haig, R.E.
Captain A. Pullan, S. C.
Mr. A. D'Souza.
„ A. D. L. Christie.
„ C. H. Mc A'Fee.
„ E. J. Connor.
„ J. Hickie.
„ G. D. Cusson.
„ G. Hall.

Sub-Surveyors.

Gopal Vishnu.
Ganesh Bapuji, 1st.
Rowji Narain.
Luxumon Ghorpuray.
Mukund Dinkar.
Bhow Govind.
Balwant Govind.
Ganesh Bapuji, 2nd.
Vital Vishnu.

(7.) On a representation being made to Lieutenant Colonel Prescott, Superintendent Guzerat Revenue Survey, acquainting him with the intention of combining the results of his survey with ours, he acquiesced to a proposal to place under my orders one of his field establishments, under an Assistant Superintendent; and on my meeting him at Súrat he drew up and forwarded a letter to Government begging for sanction for this proposal which was granted.

(8.) In the Guzerat Revenue Survey the monthly cost of a native establishment is fixed at Rs. 500, the whole of which is devoted to salaries of Native Surveyors and a few peons, but not in paying measurers, whose services are provided gratis by each village surveyed; but as this service could not be rendered gratis to the establishment working under my orders, it would have been necessary, had Colonel Prescott furnished me with an establishment of full strength, for me to have provided an additional staff of measurers at a cost of Rs. 750 a month. Therefore, as my expenditure already absorbed the whole of the funds at my disposal, I was obliged to ask Colonel Prescott to give me a small establishment, the aggregate salaries of which would not exceed Rs. 200 a month, and to make over the balance Rs. 300 a month in cash to me for the provision of a staff of measurers which he did.

(9.) Accordingly on 25th February I was joined by Mr. A. Dalzell, Assistant Superintendent Revenue Survey, who was accompanied by a Vernacular Clerk and 4 Native Surveyors as per margin.

Kuber Parbhu Das, Parbhoo Kisor, Lalu Ambaram, Gopal Ganesh.

(10.) I will now describe the method in which I availed myself of the resources of the Revenue Survey maps. The western halves of the two sheets 9 and 10 had been covered with a net-work triangulation (average of two mile sides) and the eastern halves with a system of traverses, giving a larger number of fixed points than the triangulation, on account of the greater closeness of the country. The triangulation had been executed under the orders of the late Lieutenant Colonel Nasmyth who had employed some Native Surveyors of the Revenue Survey in taking measurements from the trigonometrical stations to three or more corners of the field or "number" in which they were situated, and then from these measurements inserting the positions of the trigonometrical stations on the Revenue Survey maps. The traversing was executed under my own orders, and that in sheet 9 had been laid out so as to conform as much as possible with village boundaries; that in sheet 10 was to have been run on the same principle, but my instructions were misunderstood and scarcely any points on village boundaries were fixed by it at all; so that I had to proceed by three different methods in utilizing the Revenue Survey maps in these three differently prepared areas.

(11.) With the triangulated area I proceeded thus :—The trigonometrical stations having been plotted, as stated above, on the Revenue Survey maps, I measured (with the aid of the scale at foot of each map nominally 16 in. = 1 mile) the distances from trigonometrical stations to the

"tribhetas" (village boundary trijunctions), then with these distances (altered according to the 2-inch scale) as radii and the respective trigonometrical stations, plotted on the plane tables, as centres, I described arcs, the intersections of which gave the approximate positions of the tribhetas on the plane tables. I say "approximate" for no three arcs gave a single intersection but always a triangle sometimes very small but sometimes as large as the eightieth part of a square mile; the centre of gravity of which I accepted as the position of the tribheta. This thus gave me a series of points on the plane tables, corresponding to a number of points on the Revenue Survey maps, the details of which I was now able with a little tension here and pressure there to transfer with a pantagraph to the plane tables, which I did in blue ink, retaining a copy of the same on tracing linen in my office. This, though none of it was finally accepted on its own merits, proved a valuable assistance to the plane table surveyor, who filled in the details independently; the result of this portion alone is sufficient to prove that great use may be made of the Revenue Survey maps in improving the accuracy of our own, if we only take the trouble to make a more extensive and systematic connection between our fixed points and theirs; for the discrepancies between their details and ours consist only of small lateral displacements, excepting of course when roads and even rivers have altered their courses, which they have had time to do since the work of the Revenue Survey was executed; for the Sabarmati and the Watrak are in some places most capricious in this respect.

(12.) On the traversed portion of sheet 9, since, as stated in para: (10.), the traversing had been laid out to strike as many points on village boundaries as possible, the transferring of the details of the Revenue Survey maps to our plane tables was a very simple matter; for the tarverses once plotted on to the plane tables, we had the proper assigned limits—if not of each map—of groups of two or three maps, the details of which were easily plotted with a pantagraph. This was done in blue and the discrepancies between it and the subsequently and independently surveyed details, are very small indeed, and where they do occur are, as on the triangulated area, mere lateral displacements, attributable possibly to want of proper care in the drawing of the blue transfer.

(13.) Owing to my instructions being misunderstood, as stated in para: (10.), the traversing in sheet 10 struck on so few points recognizable in the Revenue Survey maps, that it was impossible to lay down their detail on the plane tables at all; I therefore had the village maps reduced by photography to the scale of 2-inches to the mile, and then traced from these reduced copies all the detail required on to separate pieces of transparent, tracing paper, which I made over to the plane table Surveyor, Mr. Cusson who found them most useful. Having fixed on his plane table the site of a village from which the roads emanate, and having gone round the boundary fixing the points where the roads intersected it; he then had on his plane table two points for each road between which he transferred the road from the Revenue Survey tracing. To check the roads thus plotted, he took one or more intermediate circuits, and then it was found that he could map the ground with but half the number of plane table stations that were necessary in ground of which we had no Revenue Survey maps. I regretted I had not adopted this simple method of utilizing the Revenue Survey maps over the whole of sheet 9 and 10, instead of mapping a great part of the country as I had done approximately in blue on the plane tables before they were taken into the field.

(14.) I distributed my party as follows:—Captain Pullan and two Native Surveyors, topography of western half of sheet 9. Mr. McA'Fee and 2 Native Surveyors, eastern half of sheet 9 and plane table 8 of sheet 9. Mr. D'Souza, Mr. Hall and one Native Surveyor, western half of sheet 10. Mr. Cusson and 1 Native Surveyor, eastern half of sheet 10.

Mr. Christie, triangulation in sheet 15. Mr. Connor triangulating and superintending 3 Native Surveyors traversing in sheets 2, 3, and 4 (Kattywar Nos.) Mr. Hickie being in very poor health I kept at Kaira plotting the trigonometrical stations and points on the sections of sheet 14 and a few traverses on some of the plane tables of sheet (9.)

(15.) Mr. D'Souza's work embraced almost no British territory and so entailed no special work in utilizing Revenue Survey maps, and I sent Mr. Hall who only joined the department on 22nd November 1872 with him to learn the ordinary method of plane table sketching.

(16.) After going round and seeing Captain Pullan, Mr. McA'Fee and Mr. Cusson and their native assistants at work, and shewing them how I wished them to take advantage of the Revenue Survey work, I proceeded to inspect Mr. Connor's work after which I was joined by the Revenue Survey Party under Mr. Dalzell near Sanand and about 18 miles from Ahmadabad, in sheet 2 (of the Kattyar Survey) on 25th February as stated in para: (9.)

(17.) I had during the previous month entertained a number of new hands for employment under Mr. Dalzell, and I had also prepared an equipment of theodolites, chains &c. for them, but I had to instruct him and his Native Surveyors in the method of traversing and of connecting traverses together, and traverses with triangulation hitherto adopted in this survey to which they had not been accustomed; and I had to give him systematic instructions to guide him in spreading his traverse meshes properly over sheets 2 and 3. This work of instruction kept me with him until 15th March when I left him to carry on his work.

(18.) To assist me in issuing instructions for systematic traverse operations, I requested Mr. Dalzell to bring with him from Colonel Prescott's office the original maps of all the villages in the Sanand and Dholka parganas. I had already obtained the fair copies of the general map of the Ahmadabad Collectorate, a rough compilation on the scale of $\frac{1}{4}$ inch = 1 mile, shewing the village sites and boundaries and principal roads and tanks. This map I found most useful, though it would have been more convenient had it been on double the scale. On it I sketched out a complete project of all the traversing that I saw was requisite, having first plotted approximately on it all the trigonometrical stations falling within the two sheets, and the traverses that had already been completed by the Native Surveyors under Mr. Connor, and the village base-lines, the positions of which were derived from the original village maps.

(19.) In designing the project of the traversing, the end I kept in view was to determine the position of a point close to every village site, and the positions of all tribhetas (village boundary trijunctions) which are most valuable points, as each one is a well defined point on three different village maps; this end I believe has been fully attained.

Additional measurements were taken to the points fixed near village sites, from the nearest field trijunctions, to enable them to be plotted on the village maps. In villages which had been originally surveyed by the Revenue Survey by "means of base-lines" running close to the village site, merely the ends of the base-lines were fixed, instead of fixing a point near the village site, which answers the same purpose and involves less trouble, but the proportion of such villages in the Sanand and Dholka parganas is very small indeed. In the Ulpar táluka, Súrat District, where Mr. Dalzell and his party were employed at the latter end of the season, almost every village had been surveyed with a base-line and sometimes with two or three at right-angles to each other.

(20.) After leaving Mr. Dalzell, I again went round visiting the Assistants engaged on the topography, and this time visited Mr. D'Souza and Mr. Hall whom I had no time to visit on my pervious circuit. It was when on this circuit that Captain Pullan was withdrawn to assume charge of the Kattywar Survey, which entailed several minor changes among the plane table surveyors which will appear in the separate reports of each Asssistant, which I now proceed to give in regular order.

(21.) Captain Pullan, with Rowji Narain and Mukund Dinkar, completed the topography of the western half of sheet 9.

(22.) Mr. D'Souza had entrusted to him the western half of sheet 10, comprising plane tables 1,2,5 and 6, and under him I placed Mr. Hall and Balwant Govind. He completed No. 1 himself, instructing Mr. Hall the while, and he inspected No. 2 which he entrusted to Balwant; he then divided No. 6 into two, giving one half to Mr. Hall and the other to Balwant, while he himself took up No. 5, he completed this on the 27th March and then I sent him to take Captain Pullan's place, leaving Mr. McA'Fee the easier job of supervising the completion of plane table 6. Both Mr. Hall and Balwant Govind, after the completion of the western half of sheet 10, again joined Mr. D'Souza in the eastern half of sheet 9. Besides these he had then under him Mukund Dinkar, Bhow Govind, and Vital Vishnu to complete the eastern half of sheet 9 and plane table 8 of sheet 8. The work in this portion had progressed very slowly owing to Mr. McA'Fee's sickness, and Vital Vishnu's carelessness which necessitated the whole of his work to be done over again, and for which I dispensed with his services. Mr. D'Souza's time in this part was almost entirely taken up in examining work done by others, though he himself filled in a small portion of plane table 8 of sheet 9. He only returned to Poona on 10th June.

(23). Mr. Christie was employed all the season triangulating. He first ran a series of single triangles round the margin of sheet 15, emanating from and closing on sides of Mr. D'Souza's net-work triangulation of last year, which extends slightly into the northern portion of this sheet. This I considered sufficient triangulation in flat British territory which I intended to have traversed in the same way as sheet 14. The series comprised 40 triangles and covered an area of 161 square miles. After completing this work, Mr. Christie took up some net-work triangulation in sheet 32, three-fourths of which is foreign territory, and he covered an area of 280 square miles. As he has submitted an interesting report of his season's work I attach it as an appendix to this.

(24.) Mr. McA'Fee had under him Bhow Govind and Vital Vishnu to undertake the topography of the eastern half of sheet 9 and plane table 8 of sheet 8. He was impeded by ill health during the early part of the season, but during the latter portion he was able to work well at the supervision of Mr. Hall's and Balwant Govind's work in sheet 10. He returned to Poona on the 8th May. Bhow Govind worked well.

(25.) Mr. Connor, besides supervising three Native Surveyors Gopal Vishnu, Ganesh Bapuji 1st and Ganesh Bapuji 2nd traversing in sheets 2,3,4, (Kattywar), ran two series of tri-

angles on meridians 72° 10′ and 72° 20′, emanating from sides of the Guzerat Longitudinal Series and closing on sides of the net-work triangulation carried into sheet 4 by Mr. D'Souza in 1868-69 and lying between the Sabarmati series and the series on meridian 72°; he also ran a chain of triangles about 23 miles long along the east flank of the series on 72°, as the greater portion of that ground is foreign territory and would therefore be outside the traversing operations. Each of the series run by Mr. Connor is about 31 miles long, they comprise 41 single triangles and 9 quadrilaterals, and cover an area of 330 square miles. These two series, with that on the flank of series on meridian 72° and the flank stations of the net-work triangulation in sheets 8,9,10 afforded points of departure and closing for the traverses which were eventually—with the assistance of Mr. Dalzell's party—so spread over sheets 2 and 3 as to determine the position of a point near every village site and of several points on the boundary of every village land. Mr. Connor also took some observations to determine the difference in level between the datums of the Railway and the Ahmadabad and Viramgám road, so as to enable me to convert the levels of the latter into absolute heights. He returned to Poona on 30th April.

(26.) Mr. Hickie was in too bad health to be employed on out door work, and therefore I kept him in the office working at the plotting of traverses and triangulation on the office charts, and in plotting some traverses on plane tables and also in pantagraphing village boundaries on to the sections of sheet 12. He proceeded on 6 months' sick leave from 1st March.

(27.) Mr. Cusson, assisted by Luxumon Ghorpuray, was entrusted with the topography of the eastern half of sheet 10. He completed this on the 15th May when he proceeded to join Mr. Christie to assist him in the triangulation of sheet 32. I had intended Mr. Cusson to undertake part of the triangulation of that sheet independently, but owing to unavoidable delay in providing him with a proper theodolite and equipment, this intention was abandoned and so he merely made himself generally useful to Mr. Christie.

(28.) I have been well satisfied with the diligence of all my Assistants and also with that of all the Native Surveyors, excepting Vital Vishnu who has been discharged, and Balwant Govind whose salary was reduced for carelessness. I append tabular statement showing the amount and quality of the work done by each.

Extract of Report from Mr. Christie to Major Haig.

(8.) The country in sheet 15 was one uniform level throughout, perfectly open in the Olpad táluka, west of the Tapti, and also in the Gaikwadi territory, south of the Purna river up to the Railway line: eastward it became more and more woody and consequently unfavorable for triangulation. In sheet 32 the country was perfectly open and level up to the eastern boundary of the 2nd plane table; at this point the character of the country is completely changed, high rocky hills and extensive ridges densely covered with jungle, taking the place of wide plains of open arable ground, almost entirely devoid of trees, except in and about the villages. With the change in the country, is noticeable a striking contrast in the appearance and condition of the inhabitants. Instead of the well clothed and well to do men and women living in decent weather-proof houses surrounded by many little appliances, which go towards supplying the scanty requirements of a native home, one is painfully struck with the wretchedly ragged and attenuated appearance of the hill men (mostly Bhils) and their families. The idea of abject poverty produced by the appearance of the people, is only painfully increased by sight of the wretched hovels in which they live. Their huts are with hardly any exception, mere grass sheds affording the most meagre shelter from the inclemency of the weather, owing to the clumsy, careless manner in which they are put up. In the month of May when thunderstorms, accompanied with heavy falls of rain, were of almost nightly occurrence, their huts were in so dilapidated a state as to offer barely more protection than might be afforded by a good sized umbrella. Altogether the utter indifference for creature comforts displayed by the Bhils, is perfectly surprising. Although the country further on is very hilly and densely wooded, I am told carts are used throughout. A very small portion of the land is under cultivation owing to the scanty population which is almost entirely composed of Bhils, whose chief occupation consists in felling timber, which they carry for sale to the nearest market. Good water is obtainable at almost every village though wells are few in number; the want of them being met by pits dug in the sandy beds of the nallas with which the country is everywhere intersected.

(9.) At the village of Ratanpur I came across large pits which had been excavated to obtain the well known "Cambay Stone" which are here found in large quantities. These pits are worked by agents of the Cambay Lapidaries. After collecting sufficient quantities they burn them in kilns when only such as assume a bright translucent appearance are retained; these are then packed up in gunny bags and carted to Cambay.

(10.) Wild animals are numerous though owing to the heavy cover very difficult to get at. From the closest inquiries I could make, I was surprised to learn that these jungles up to at least the meridian of 73° 30′ are not at all malarious even in the cold weather, This seems to be borne out by the appearance of the natives who though lean and squalid from poor living, present none of the miserable effects of systems emaciated by disease so noticeable in tracts notoriously feverish such as the forests in North Canada.

TABULAR STATEMENT OF WORK IN GUZRAT, DURING THE FIELD SEASON 1872-73.

Triangulation.

Observer's Names.	Instrument used.	Area triangulated.	No. of stations visited.	3 Angles observed.				2 Angles observed.			Remarks.
				Triangles.	Triangular error.	Error per mile.	No. of Heights.	Triangles.	Error per mile.	No. of points.	
					"						
Mr. A. Christie, ...	6" by Troughton & Simms'	441	63	90	10·1	Not known	59	578	Not known	366	39 tribhetas and 14 boundary marks fixed by azimuths and distances. Total distance chained 39 miles.
						Feet					
„ E. J. Connor, ...	Ditto	330	60	78	16	0·5	50	234	„	133	51 tribhetas fixed by azimuths and distances. Total distance chained 52 miles.
	Total, ...	791	123	168	.....	.....	109	812	.....	499	

Plane Tabling.

No.	Names.	Plane Tabling.	Stations per square mile.	Remarks.
1	Captain A. Pullan, S.C. ...	120·0	8·1	
2	Mr. A. D'Souza, ...	180·0	8·5	Examined 360 square miles.
3	„ C. H. McAFee, ...	35·3	12·0	Do. 132 do.
4	„ G. D. Cusson, ...	168·0	6·0	
5	„ G. Hall, ...	54·0	17·4	Do. 36 do.
	Native Surveyors.			
1	Rowji Narain, ...	120·0	10·3	
2	Luxumon Ghorpuray, ...	121·0	8·0	
3	Balwant Govind, ...	167·0	10·8	
4	Mukund Dinkar, ...	113·0	12·3	
5	Bhow Govind, ...	168·0	17·0	
	Total	1236·3	11·0	Mean.

Traversing.

No.	Names.	Linear miles of Traverse.	Remarks.
	Native Surveyors.		
1	Gopal Vishnu, ...	175·0	
2	Ganesh Bapuji, 1st	130·1	
3	Ganesh Bapuji, 2nd	226·0	
	Revenue Surveyors.		
1	Kuber Parbhu Das, ...	59·8	
2	Lalu Ambaram, ...	57·5	
3	Gopal Ganesh, ...	56·7	
4	Parbhoo Kisor, ...	67·8	
	Total	772·9	

Extract from the Narrative Report—dated 25th September 1873—of Lieutenant J. HILL, R.E., Offg. Dy. Superintendent 2nd Grade, in charge Kumaon and Gurhwal Survey Party.

The Recess of 1872.

The party was employed during the recess of 1872 on computation and mapping, including the preparation of four fair sheets of the Kumaon and Gurhwal Survey which were completed and sent for publication to the head-quarters office at Dehra Dún before the party took the field.

Plan of operations for the field season.

(2.) The plan of operations for the field season was as follows:—1st, to send in September two assistants to survey topographically the whole of the Mána Valley and a portion of country in the eastern half of Sheet XII which had been left unfinished in 1868: 2nd, in November, when the weather becomes too cold to carry on a survey in such elevated regions, to move those two assistants southwards to commence the topography of Sheets XXI and XXII; and 3rd, to employ the main strength of the party (recess duties being done) on the topography of the following districts, viz:, the Bhábar tracts from Haldwáni eastwards to the Sárdah river, the lake country to the east of Naini-Tál, the country round Lohu Ghát, and those portions of the Gori and Rámganga Valleys which lie in the vicinity of Askot. In addition to providing for the above work, which all lies in Kumaon and British Gurhwal, the plan of operations had to include arrangements for commencing a triangulation to the west of the Ganges and its tributary the Mandagni river with the object of providing points for a topographical survey of Tíri Gurhwal, Dehra Dún, Jaunsár and Báwar in the first instance, and subsequently for the survey of other districts to the westward.

The field season of 1872-73.

(3.) With the above objects in view, the party took the field as follows:—Messrs. L. Pocock and H. Todd started for the Mána Valley on the 27th September. Lieutenant Harman started for Naini-Tál on the 1st November. Messrs. J. Peyton and J. Low left on the 9th November, the former for the Bhábar hills east of Haldwáni, the latter for Lohu Ghát, and Mr. E. F. Litchfield left on the same day to take up his work to the east of Naini-Tál. On the 22nd November Mr. E. C. Ryall started for the Bhábar tracts near Haldwáni, and Mr. T. Kinney, who had been detained in quarters later than the other assistants to examine maps and to accompany the civil authorities on their inspection of the boundary of Masúri and Landaur, started on the 4th December for his work near Debi Dhúra to the east of Naini-Tál.

(4.) When the assistants had left head-quarters, I commenced my march to Haldwáni, taking with me as my office assistant Mr I. Pocock, who had lately joined the Department. Our road lay through Hardwár, and on arriving there I made an inspection of the staving done by men whom I had sent out before the end of the recess to prepare for the commencement of the new triangulation of Dehra Dún, &c., and in spite of very hazy weather I succeeded in taking observations from three stations. I then continued my march to Haldwáni, which I made my head-quarters until the 19th March, when I moved them to Almora. During the greater part of the season, while my head-quarters were stationary at Haldwáni and Almora, I was travelling about with a small camp inspecting the work in Sheets XXV, XXVI, XXXI, XXXIII and XXXIV. On the 7th May I despatched the head-quarters camp in charge of Mr. I. Pocock by the plains road back to Dehra, and I myself left Almora with a very light camp to inspect the work in Sheets XXI and XXII, and in the Mána Valley: that done, I returned through the hills to Masúri, arriving there on the 7th June.

(5.) I now proceed to report separately on each officer's work, the details of which are tabulated on page 37—a.

Lieutenant H. J. Harman, R. E.

(6.) Lieutenant Harman's ground was of three distinct varieties. To the north he had to sketch the lake country which includes Naini-Tál, Bhím-Tál, Sát-Tál and Naukuchia-Tál. In this district the differences of level are very great, and the ground, which is crowded with important details, is also so complicated that in many instances the 1-inch scale was found inadequate to represent all its characteristic features. Southwards the ground changes its character; the limestone of the lake district giving place to intricate sandstone hills resembling the Sewáliks. The northern slopes of these sandstone hills are more cultivated than any other similar ground in Kumaon or Gurhwal (probably on account of the proximity of Naini-Tál and the good roads which pass through this district to the plains), their southern slopes however are uncultivated. At the foot of these southern slopes lie the flat tracts of the Bhábar. They are in general covered with *Sál* forest on the more raised plateaux, and on the lower flats with *Khair* and *Sissu* and other jungle. Of late years owing to the exertions of the present Commissioner of Kumaon considerable portions have been cleared and irrigated, and in the neighbourhood of Haldwáni in particular there is now a large extent of cultivated land.

DETAILS OF TOPOGRAPHY ON SCALE OF 1 INCH = 1 MILE. KUMAON AND GURHWAL PARTY. SEASON 1872-73.

NAMES.	Area surveyed, in square miles.	Number of Plane Table Stations.	Average number of Plane Table Stations per square mile.	Length of Traverse lines in miles.	Length of Traverse lines cleared in miles.	Number of Boundary pillars fixed.	Area under cultivation in square miles.	Range of altitude above Sea level, in feet.	Average rate of work per diem, in square miles.	REMARKS.
Lieut. H. J. Harman, R.E., ...	70	230	3·1	...	...	...	8	1400 to 5000	2·1	Densely wooded and intricate sandstone hills, terminating in the Bhábar flats.
	41	134	3·3	...	...	...	7	2000 „ 8200	2·0	Lake country near Naini-Tál. Intricate, and in general covered with forest.
	157	...	...	191	157	9	33	780 „ 1400	3·6	Bhábar flats, chiefly covered with dense forest and jungle.
E. C. Ryall, Esq., ...	116	255	2·2	...	...	...	0	900 „ 5700	3·3	Densely wooded and intricate sandstone hills, terminating in the Bhábar flats.
	*184	...	...	382	324	32	4	800 „ 1200	4·4	Bhábar flats, chiefly covered with dense forest and jungle.
Mr. J. Peyton, ...	100	150	1·5	...	...	...	3	3000 „ 16000	5·0	Mixed ground in the Gori Valley, partly forest, partly open, including lower spurs of snowy ranges.
	*280	550	2·0	...	...	...	14	1300 „ 7000	4·0	Densely wooded and intricate Bhábar hills, and hills to their north of a simpler character.
„ J. Low, ...	172	416	2·4	...	...	...	64	1700 „ 7000	3·0	Mixed ground, including the cultivated gently-sloping hills of Lohu Ghát.
	258	646	2·5	...	...	...	31	2500 „ 8900	2·5	Mixed ground in the Rámganga Valley, with comparatively bold features, and much forest.
„ L. Pocock, ...	335	104	0·3	...	...	...	1	6000 „ 25000	14·0	Bold high ground in the Mána Valley, culminating in some of the loftiest Himalayan peaks.
	199	150	0·8	...	...	...	11	3500 „ 20000	5·5	Ground south of the foregoing, also with very bold and commanding features.
„ H. Todd, ...	88	26	0·3	...	...	...	1	5000 „ 21000	9·0	Ditto ditto.
	200	130	0·7	...	...	...	9	4000 „ 21000	5·2	Ditto ditto.
„ T. Kinney, ...	260	511	2·0	...	...	...	38	2700 „ 7500	3·4	Mixed ground east of Naini-Tál, in some parts covered with dense forest.
„ E. F. Litchfield, ...	174	320	1·8	...	...	...	21	2700 „ 8200	2·4	Ground east of Naini-Tál and adjoining the lake district, chiefly covered with forest.
	100	180	1·8	...	...	...	8	3000 „ 12000	3·7	Mixed ground in the Gori Valley with comparatively bold features, and much forest.
TOTAL, ...	2734	...	...	573	481	41	253	...	...	* These areas include 55 square miles of the Nepál border sketched from Kumaon.

Details of Triangulation.

NAMES.	Area triangulated, in square miles.	Number of Stations visited.	Number of points fixed by intersection but not visited.	Number of stations whose positions and heights have been fixed.	Number of stations whose positions only have been fixed.	Number of hill tops cleared of forest.	Average area in square miles to each trigonometrical point.	Average area in square miles to each trigonometrical height.	Number of triangles of which all 3 angles have been observed.	Number of triangles of which only 2 angles have been observed.	Number of points whose elements have been computed.	REMARKS.
E. C. Ryall, Esqr., ...	270	21	† 7	27	0	2	10·0	10·0	15	11	...	Bhábar district east of Haldwáni, and Naini-Tál.
Mr. L. Pocock, ...	83	9	59	55	13	41	1·2	1·5	7	87	...	Dehra Dún.
Total, ...	353	30	66	82	13	43	...	...	22	98	203	† This number includes 4 peaks in Nepál.

(9.) Lieutenant Harman's field work consisted in surveying topographically 268 square miles of most intricate country, in helping Mr. Ryall for a week at computations, and in doing the work specified in the two preceding paragraphs. This was an excellent season's work; large in amount and, as I found on inspection, of a very thorough and satisfactory character.

E. C. Ryall, Esq.

(10.) The portion of country surveyed by Mr. Ryall adjoins and lies to the east of Lieutenant Harman's Bhábar ground, which it resembles only in a general way. To the north it rises into sandstone hills of the Sewálik formation which are thickly covered with *sál*, *dhau* and *chír* forest. Below these hills are flats of a much wilder character than those lying to the westward. The flats are here almost free from irrigated clearings except at Barmdeo; they are very densely wooded, and are intersected by numerous tortuous streams and watercourses, intermingled with swamps, cane and bamboo jungle. This ground presents great obstacles to the Surveyor. Its climate only admits of work being carried on without great danger to health during the months of December, January and February, during which time the jungle grass is high, and the Surveyor, shut in on all sides, is obliged to have his way laboriously cut before him, and is restricted exclusively to the traverse method of surveying in order to map the hidden features of the country.

(11.) While Mr. Ryall was surveying this difficult tract of country, he carried on hand in hand with his topography a minor triangulation to determine the positions of some points which were required for traverse purposes. He computed out the elements of these points in the field with Lieutenant Harman's assistance; and I may here remark that he also employed himself on computations while marching to his ground at the commencement of the field season. He finished his topography on the 1st May and then went to Naini-Tál to determine trigonometrically the height of the Naini-Tál lake. After his arrival there he was weather-bound for some days, but on the 8th May he completed the necessary observations; and, his field work being done, he started for recess quarters.

(12.) Mr. Ryall's out-turn of work is, as usual, large. His survey embraces an area of 270 square miles, and its execution is in all respects most creditable to him.

Mr. J. Peyton.

(13.) Mr. Peyton's survey was exclusively topographical and was confined to hilly country. His first piece of work consisted in sketching the portion of the Bhábar hills which lie immediately to the north of Lieutenant Harman's and Mr. Ryall's Bhábar survey. The southern part of this hilly tract is especially troublesome to sketch, owing to the denseness of the forest with which it is covered, and to the sparseness of the population and the consequent difficulty in procuring coolies. Proceeding northwards the hills become simpler in their character, more free from forest and less thinly inhabited, and sketching becomes proportionately easier. Mr. Peyton finished the survey of this tract of country on the 12th March, and then started to take up his second piece of work, which includes Askot and part of the eastern side of the Gori Valley.

(14.) Within the northern limits of this second portion of his survey are some of the spurs of the snowy range which separates the Gori Valley from the wild district of Dharma. A very unusual fall of snow commenced about the end of April and continued, off and on, for about a fortnight, rendering the high ground inaccessible and obliging Mr. Peyton to close work on the 17th May without having quite finished the work allotted to him. Besides the obstruction caused by snow, his work was retarded by a very extraordinary fog which lasted during the greater part of April and which, while at its thickest, rendered objects invisible at a distance of a couple of hundred yards. In spite of these drawbacks Mr. Peyton succeeded during the field season in surveying 380 square miles of country, all the varied features of which he delineated with his usual artistic skill.

Mr. J. Low.

(15.) Mr. Low was employed during the field season on the topography of two separate portions of Kumaon. Towards the close of the season he commenced, and he is still engaged upon a triangulation of the Juár Valley; but as its details belong properly to the year 1873-74 they are not included in the present Report. His first duty was to finish the survey (commenced during the previous field season by Mr. L. Pocock) of the portion of country which includes Lohu Ghát and lies between Pathoragarh and Champáwat, descriptions of which places are contained in paras: (19.) and (23.) of my last year's Narrative Report. The country surveyed by Mr. Low is of a character similar to what is there described. Broad open flats, looking from a distance almost like one plain and terminating on the north-west in a very sudden fall, reach from the now deserted station of Lohu Ghát to Deo Náth, where a gently undulating country commences which extends as far westward as Debi Dhúra. Mr. Low finished his survey of this tract of country by the middle of February and then started to take up his second piece of work which consisted in sketching the portion of the Rámganga Valley which lies near Askot and is included in the westerm half of Sheet XXXI. This portion of country does not call for a fuller description than what is contained in the tabular statement on page 37—a It is situated close to the country mentioned in para: (14.) but as it does not quite attain in any part to an

altitude of even 9000 feet above sea level, Mr. Low was not compelled to close work in consequence of the bad weather described in that paragraph. His work was much delayed however by the dense fog and by the rain, and his health being also very indifferent he did not succeed in finishing his topographical work until the end of June.

(16.) During the field season Mr. Low completed the sketching of 430 square miles of hill country. The improvement in his sketching this year is very remarkable. His Rámganga plane-table sketch, his most recent piece of work, is far better than anything he has hitherto turned out and is in every respect a very creditable performance.

Mr. L. Pocock.

(17.) Mr. Pocock reached his ground in the Mána Valley on the 12th October and commenced his sketching close to the famous temple of Badrináth. I subjoin the notes he made while working in this very interesting portion of country.

"The portion of the Mána Valley surveyed by me lies in the *Pati* of Pailkhanda, *Zillah* Gurhwal. The climate is very cold in October and November. Towards the end of October the people begin to leave the valley for Chamoli and Karn Prág, and by the 25th November not a soul remains at Mána. They do not return to their villages till the months of May and June when the snow is sufficiently thawed to admit of their doing so. The ground which I have sketched is most precipitous and in many parts it is quite inaccessible.

At Mána itself and on the surrounding mountains there is no forest, but lower down—commencing from Benakuli where the Mána people collect their wood supply in April, May and June—wood of various kinds is to be found. At Mána the only grain which grows is *kotu páhpar*, the seed being put down in May and the harvest cut in September. The soil is so poor that it will not yield but every other year, and the produce is then only about 200 maunds. This *kotu* is eaten uncooked by the Mána people after simply making a mash of the flour; their breakfast consists of this as a rule. There is near Mána a fine piece of level ground on either side of the Alaknanda river which is used for cultivation. The mode of cultivation is similar to what is used all over Gurhwal. After sowing their fields, the majority of the *men* go off with barley, rice, flour, *kotu* and a small quantity of *gur*, laden on goats and sheep, to Tulingmat and Chaurangghar in Thibet. This barley, rice, &c. is brought up from Rámnagar and Kohdwára during the winter months in exchange for salt and borax taken down. In all, over three thousand goat-loads of salt are brought into Mána by the Mána people and by Bhoteas; the latter coming over the pass when they are hard pressed for barley and rice.

That part of the river Alaknanda (including its northern tributary the Susawati) which lies in my work has its source from several glaciers, and is not anywhere fordable, both on account of its depth and great velocity. Its bed is of boulders, and the stream even in October and November is frozen along the sides, and would be so entirely but for the friction caused by its violent motion.

There is a small three-cornered lake (each corner having a name) near Mána called Satopant or Karchákul which is considered holy. It is said that it is fathomless and that no bird can fly across it, and it is resorted to by a few of the pilgrims who go to Badrináth. The people of the Mána Valley throw the ashes of their dead into it, and they also make several offerings at the lake to propitiate the deity who is supposed to inhabit the spot, so that the pass may not be blocked up and closed for traffic by heavy falls of snow, which they believe would be the case if these offerings were neglected.

The Badrináth Temple is very well known all over India, and is presided over by a high priest called the Raulji or Raul Sáhib, who is a Bráhman of the Deccan of the highest caste. This temple is allowed a revenue from the Government, a number of villages in Gurhwal and Kumaon being obliged to pay to the Raulji. The deity Badrináth is considered the most holy, because supposed to be self-created, and for this reason even more sacred than Jagarnáth. (Jagarnáth is of wood carved by a carpenter; hence the tradition among the natives of this country that carpenters never attain a ripe age.) The idol of Badrináth is of some fine black stone which has the appearance of marble. In a good season twenty-five to thirty thousand rupees are offered up at the Badrináth shrine, and the amount allowed by Government is seven thousand rupees; notwithstanding this the temple is involved a good deal in debt. The debt appears to have been handed down. All the dishes in the temple are of pure silver, and the top of the temple is covered with a wash of gold.

The Márchas, or Mána people, are fine strong fellows but are greatly addicted to drinking a horrible liquor which they extract from rice and other grains. The Márchas though they profess to be Rájpúts, without the sacred thread, are of a low caste, and are not allowed to enter the temple of Badrináth. They are well to do, and besides their sheep and goats they own ponies, Thibetan dogs, yáks and jobas. The yák is very sure footed and does to ride. The joba is a cross between the yák and the cow and is even a more useful animal than the yák, as he can endure greater extremes of heat and cold.

On the road from the Badrináth Temple to the Satopant Lake is a water-fall called Bosidhára which is believed to stop flowing on being sighted by anybody of immoral or bad character The Márchas firmly believe this and tell a story of such a thing occurring during the time when the British were taking Kumaon and Gurhwal. The Rája of Kumaon believing that by making a pilgrimage to the Satopant lake the progress of the English would be stopped, determined on doing so; but no sooner did his eyes rest on Bosidhára than it ceased to flow, for he was a tyrant and an oppressor of his people.

The road along the river in my portion of the work is very good as far as Mána. Above that it is very bad in some parts. Just near Mána the road crosses from the left to the right bank over a natural bridge formed by an immense rock under which the river flows. Here too the river has a fall of over a hundred feet.

The *Bhojpata* or birch—met with here just below the limits of perpetual snow—is a very useful tree. The trunk is used for *ballis* or rafters and the bark (*shág*) placed over these and pressed down with earth, forms the roofing of the houses."

(18.) Some further information regarding this part of Gurhwal is contained in para. (7.) of my last year's Narrative Report.

(19.) Mr. Pocock finished his work in the Mána Valley on the 8th November and then marched southwards to take up the sketching of the western portion of Sheet XXII. This part of the country is thickly covered with forest. It contains some very high ground; but in general it is of a moderate elevation, the highest point here visited by Mr. Pocock being about 12,400 feet above sea level, and the majority of his stations being very much lower.

(21.) By reference to the table on page 37—a, it will be seen that in spite of illness Mr. Pocock turned out a large amount of work, his topography embracing an area of 534 square miles and his triangulation an area of 83 square miles. This large out-turn is of a very satisfactory character. His sketching has been carefully done, and, though he still lacks the manua-

skill which has been attained to by most of the other members of the party, his style of sketching is steadily improving.

(22.) Mr. Todd was directed to sketch the part of the Mána Valley which extends from the upper limit of Mr. Pocock's work as far northwards as the Mána Pass. In accordance with his instructions he made for the pass as rapidly as possible so as to commence his sketching there and to work downwards as the intensity of the cold increased. On the 26th October he reported to me that he had been obliged to abandon this piece of work owing to the utter insufficiency of the triangulation, and that he had come down from the pass and commenced sketching to the south of Mr. Pocock. During the time that Mr. Todd was up near the Mána Pass he spared neither himself nor his establishment, but did his best, I believe, to fix his position and commence his sketching, though unfortunately without success. The season was an exceptionally severe one, the thermometer at noon on the pass standing at 12° below freezing point, and by the time Mr. Todd reached his ground south of Mr. Pocock both he and his establishment were much knocked up; but in spite of this he worked hard and by the 12th November he had completed 88 square miles of survey.

Mr. H. Todd.

(23.) On receiving Mr. Todd's report I wrote to Mr. J. Low who had triangulated the Mána Valley for his explanation of the alleged failure in his triangulation. He stated in his reply that he considered the points he laid down were sufficient for the purposes of plane-tabling, and that he would undertake to sketch the ground in question himself without any additional trigonometrical stations. Here the matter rests for the present; for although I had intended to decide the question when I made my inspection of the Mána work in May, I was unable to do so as the people had not returned to their villages and all the valley was closed beyond the village of Mána which was the extreme point I was able to reach.

(24.) On completing the work specified in para. (22), Mr. Todd marched south and commenced, on the 19th November, the sketching of the western portion of Sheet XXI. The following are his notes on this part of the country.

"This piece of work comprises portions of Painkhanda and Malla and Talla Dasoli. The country is intersected by three immense spurs jutting out from the snowy range of Trisúl and terminated by the river Alaknanda. The northern faces of these spurs are of easy slope and densely covered with chestnut, hazelnut and fir trees. The villages are few in number and the cultivation very limited. The ground under cultivation yields sufficient crops for the support of the villagers; the surplus finds a ready sale among the Márchas (the inhabitants of the Mána and Níti Valleys) whom the severity of the climate during winter compels to migrate to these parts. Another means of support is the rearing of the carrier sheep for which the nature of the country is well adapted affording, as it does, very extensive pasturage. These sheep are readily purchased by the Márchas for trading purposes. The road running along the left bank of the Alaknanda, and along which the trade is chiefly carried on, is, for the greater portion, in very fair order. The upper road *viâ* Rámni to Joshimat and Níti is a very narrow one, with very steep ascents and descents."

(25.) While working here Mr. Todd's health, which had suffered severely from his exposure to the great cold in the Mána Valley, completely broke down. In his anxiety to do a good season's work he was too long silent regarding his illness; but at last (and after he had succeeded in finishing more than two-thirds of his plane table) he reported that his illness had increased alarmingly and he forwarded a medical certificate recommending that he should be given work in a warmer part of the country. On receiving it I directed him to march to Debi Dhúra and there join Mr. Kinney who would give him a plane table I had sent him for the purpose. Mr. Todd accordingly marched for Debi Dhúra and arrived there on the 29th January. Mr. Kinney was then a couple of days march distant, but on hearing of Mr. Todd's arrival he went at once to Debi Dhúra and found Mr. Todd so seriously ill, both bodily and mentally, that it was necessary for Mr. Kinney to accompany him to Almora which was the nearest place where medical assistance could be obtained. The Civil Surgeon of Almora recommended that Mr. Todd should at once stop work and go on leave; I therefore sent him with that object to Dehra, where he arrived on the 18th February.

(26.) Mr. Todd was able to complete the sketching of 288 square miles before his illness compelled him to stop working. I found his work, as usual, both as regards its accuracy and its execution to be thoroughly satisfactory.

(27.) Mr. Kinney reached his ground near Debi Dhúra and commenced his sketching on the 26th December. The part of the country he surveyed lies to the east of Naini-Tál and, as regards its general character, is like ground of a similar altitude elsewhere in Kumaon. The following are some extracts from the notes made by Mr. Kinney while he was carrying on his survey.

Mr. T. Kinney.

"Debi Dhúra is rather a pretty spot with comparatively level ground broken by ravines; some of the spurs being cleared and cultivated, while some are covered with oak and rhododendron. About the temples and *dharmsálas* there are a few deodars also, some of them very fine trees and apparently of considerable age. There are two temples here, or rather shrines, for no actual temple now exists, though there are evidences of one or more having been here formerly, in the fragments of carved stones lying about and built into the *dharmsálas*, some few blocks which look like capitals of pillars being still perfect. The two shrines are sacred to two distinct deities; the minor one, which is on the top of the hill, being dedicated to a *Deota* (masculine) who is supposed to be a Rájpút; the principal one being that of the *Debi* (female) and having a resident Bráhman priest. This latter shrine is situated at the base of a cavity formed by two enormous boulders whose tops rest against each other at a height of about 40 feet from the ground. There are many such boulders scattered about the immediate neighbourhood, some even of greater size than the two forming the temple. The ground about Debi Dhúra is remarkably well watered, almost every little ravine having water in it. A number of

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

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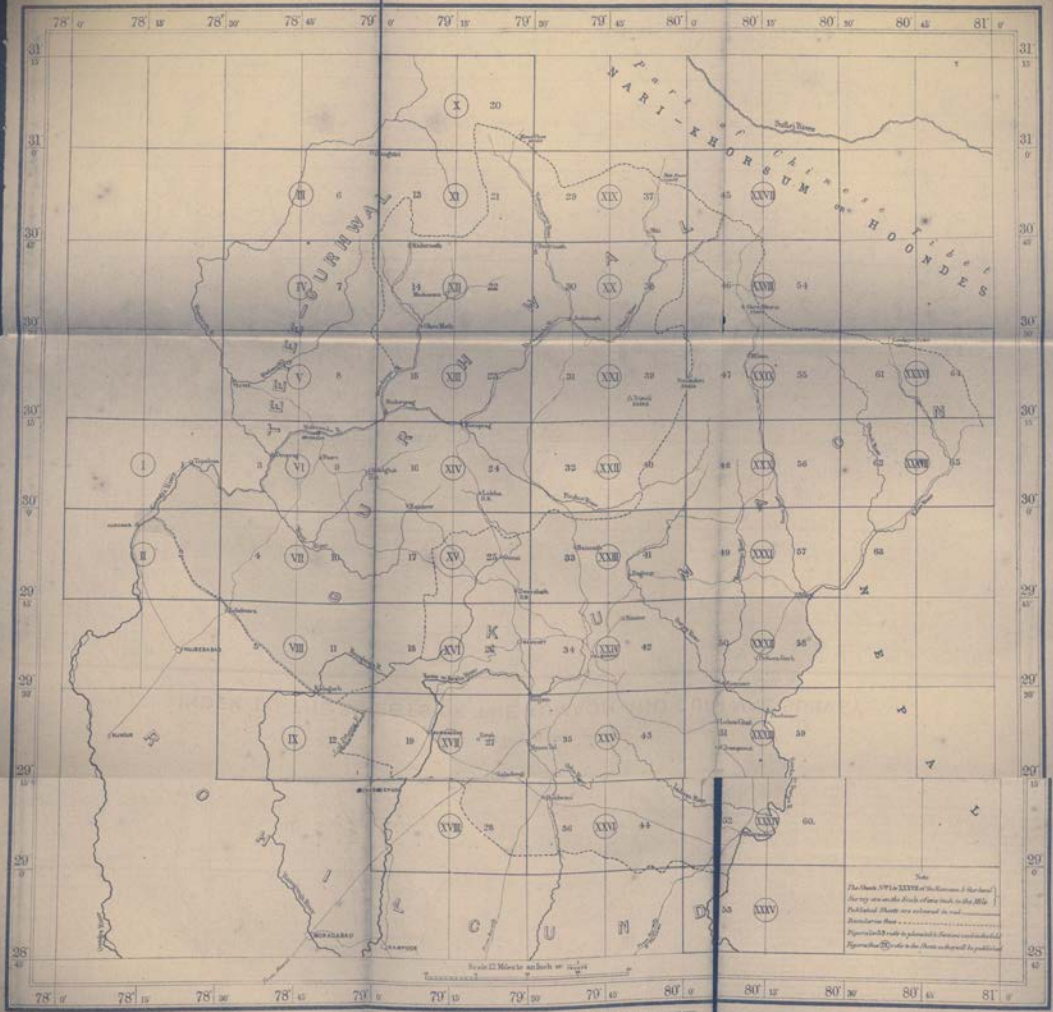


COMPILED UNDER THE DIRECTION OF MAJOR T. G. MONTGOMERIE, R.E. CHIEF OFFICER GREAT TRIGONOMETRICAL SURVEY OF INDIA.

Photolithographed at the G. T. Survey Office, Dehra Dun November 1875.

dharmsálas are built near the principal shrine for the accommodation of the people who visit it at the annual *mela*, or festival, which is held in the month of *Sáwan* (June—July). I am informed that a stone throwing fight generally winds up the *mela*—I can obtain no other reason for this annual skirmish (in which it is said men are occasionally severely wounded) but that it pleases the Debi.

The ground in the southern portion of my plane-table section is much bolder, and the ridges generally are considerably higher than in any other part. Another peculiarity of the topography of this part of the country is the occasional lowness of the watersheds: between two high points the ridge, in some instances, suddenly sinks so low that unless one were to stand on the actual pass or saddle formed by the sinking of the ridge it would be difficult to believe that one did not see two spurs running down from distinct ridges into a valley between.

On the southern ridge of the Deogúr hill the oak forest is remarkably fine, the trees growing thickly together and attaining a great size: they are very straight too, some of them as tall and straight as the largest *chír* pines, and they are also branchless to a considerable height. I should imagine that this forest, extending as it does a considerable distance along the ridge, would be of great value.

At Manglalek there are iron mines which are partly worked by Doms from various surrounding places, but chiefly by those of Manglalek itself and of Nai village in the Chaubhainsi *Pati*. The ore is smelted down in the valley of the Ladhia river at a place called Bori-ka-khera, which is also a depôt for the sale of the iron, as the *lohárs* from all parts of the surrounding district come to Bori to purchase the rough metal for their work. The mine now worked is situated below the village of Manglalek—between it and Salián—the former workings in the village of Manglalek itself have been abandoned since last year.

The portion of Chúlsi *Pati* to the N. and N.E. of Debi Dhúra as far as Gágar and Múlakot is most extraordinarily well cultivated; not a trace of jungle or even of waste land can be seen, and the steepest ravines are terraced to the very bottom. There are no less than thirty villages—many of them very large ones too—within an area of some eight or nine square miles.

The road from Debi Dhúra *viá* Jenti to Charonj, the point of its junction with the main district road a few miles north of Dol, is a new road, having been made only some 16 years ago, while the other road has been in existence since the Katúr Ráj, having been merely improved and repaired by the British Government. The new road, though it lessens the distance from Almora to Debi Dhúra considerably, is a very steep one and is very little used; the district dák, however runs on this road—the dák chaukies between Almora and Debi Dhúra being at Charonj and Jenti."

(28.) Although Mr. Kinney did not reach his ground until the field season was far advanced, and though he lost some days in attending on Mr. Todd, he completed the sketching of a full plane-table section on the 16th April. His work has been carefully and well done, and, as usual, he has given me complete satisfaction.

Mr. E. F. Litchfield.

(29.) Mr. Litchfield commenced to plane-table the part of country allotted to him east of Naini-Tál on the last day of November. This piece of country, which separates the hilly country surveyed by Lieutenant Harman from Mr. Kinney's ground, is intersected by good district roads and is in general very thickly covered with forest; it contains one lake (Malwa Tál), and it is also remarkable for a very sacred peak called Kailás Parbat which is annually visited by hundreds of pilgrims. Mr. Litchfield finished his work here on the last day of February, and then marched to take up his second piece of work, which consisted in sketching that part of the Gori Valley, in Sheet XXXI, which lies between the ground assigned for survey to Messrs. Peyton and Low. This piece of country calls for little description: it is chiefly remarkable for the number of roads which have been cut through it by an enterprising Thibetan named Dhannu for the benefit of his countrymen who trade in salt and borax. While working here Mr. Litchfield was much hindered by the thick fog and bad weather already noticed in para. (14); he also unfortunately became very ill towards the end of the field season and was obliged to close work on the 22nd April without having quite finished his sketching.

(30.) Mr. Litchfield's field work consisted in sketching 274 square miles of hilly country, all of which work I found very carefully and satisfactorily done.

Mr. I. Pocock.

(31.) Mr. I. Pocock joined the Department on the 28th October and was posted to this party on the same day. I have employed him on various duties, all of which he has performed to my satisfaction. He has acted as my recorder, and has learnt to use an 8-inch theodolite. During my inspection tours he has taken charge of the head-quarters camp. As a rule he has been employed in my office on current work and on the ordinary computations which are carried on in a topographical party. He has applied himself diligently to learn his work, and has proved himself to be a valuable office assistant.

Health of the party.

(32.) The health of the party during the field season was not good. Nearly every assistant suffered more or less from ill health, and there were many bad cases of fever among the native establishment. The men working in the Bhábar suffered most, Mr. Ryall at one time having only one-fourth of his men fit for duty. A severe out-break of cholera also took place in the district about the beginning of February and the country under survey was not free from the epidemic during the whole of the remainder of the field season. Although the district suffered severely from this out-break of cholera, the survey establishment escaped with very few fatal cases.

General Review of the field operations.

(33.) In spite of many drawbacks the field season was, I think, a successful one. The weather was, in general, most unfavourable to survey operations. The winter set in in the Mána Valley unusually early and with exceptional severity. Elsewhere there was much fog and rain. The health

of the assistants was not good, and three of them were compelled by illness to stop working before the end of the field season. Labour was very scarce over the greater part of the country under survey, and in the Bhábar in particular it was with the greatest difficulty that the panic-stricken inhabitants, flying from the cholera, could be prevailed upon to give any assistance to the surveyors. Whole districts were deserted, and in such places the survey could only be carried on by the expensive plan of hiring permanent coolies from elsewhere. In such a country also as Kumaon, some parts of which are deadly and others inaccessible at certain seasons of the year, and where consequently the climatic changes must influence the movements of surveyors, much precious time is unavoidably lost in marching. Yet, by the end of the field season the large area of 2734 square miles had been topographically surveyed.

(34.) On reference to page 37—a, it will be seen that there is little uniformity in the daily rates of work there tabulated. This is due to the great variety in the physical characteristics of the country surveyed, which includes ground of all kinds, from the low swampy plains of the Bhábar and Tarai to the inaccessible snowy ranges which separate British territory from Chinese Thibet. In the high ground among the snowy ranges where the surveyor can exercise little choice in the selection of his stations, but must be content to sketch the country from such points as are accessible to him, a survey partakes somewhat of the nature of a reconnaissance and can be carried on at the rapid rate of from 9 to 14 square miles a day. In the moderately high ground of the Sub-Himalayas a good surveyor works at an average rate of about 3 square miles a day; while in the flat Bhábar tracts, where the method of survey employed is that of straight parallel traverses, the daily rate of work is about 4 square miles. It will thus be seen that for a country like Kumaon no rule can be framed to fix one good uniform rate of work, or, which comes to much the same thing, one uniform number of plane-table stations per square mile.

(35.) While on the subject of the methods of surveying employed by this party I may remark that a plan for recording plane-table traverses has been in use for the last two years and has been found to answer its purpose. A circle is described round the graticule on the plane table and graduated to quarters of a degree from left to right, commencing from the south—(or an ordnance survey cardboard protracter may be used instead). In traversing, the azimuths of back and forward stations and of trigonometrical points are taken by placing the sight rule over the centre of the circle, intersecting the objects, and then reading the angles off the graduated circumference. This can be done very quickly, for between each observation it is not necessary (as it is with a prismatic compass) to wait while the needle comes to rest. The azimuths also are referrible to the true meridian and are not mere compass bearings: they are therefore all the more quickly plotted on an ordinary graticule; and having been read off a circle of large diameter, they possess considerable accuracy. The azimuths, chained distances &c. are entered in a field book, and a record is thus preserved which is capable of being utilized at any future time, and which would prove very convenient if an enlargement of the scale of the survey became necessary.

The present recess of 1873.

(37.) Since the commencement of the present recess the party has been employed on computations, and on the preparation of the fair maps of the country surveyed during the past field season, four of which maps should be ready for publication before the party again takes the field.

Extract from the Narrative Report—dated 5th August 1873—of Captain J. HERSCHEL, R.E., Deputy Superintendent 2nd Grade, in charge Astronomical Party No. 1.

Subjects of this report.

(2.) My principal subject will necessarily be that to which the field season of 1872-73 was devoted, namely the experimental determination of longitude-differences; but before entering upon that it is necessary that the subject of former reports should be brought to a conclusion. I refer to the latitude operations on the Central Indian Meridian.

Additional comparisons of Astronomic with Geodetic latitudes.

(3.) The general results arrived at were presented in a tabular statement in the postscript to my last report: there is little to add to that statement so far as astronomic co-latitudes are concerned. The geodetic elements of the SOMTANA and BADGAON groups have been sent to me, giving the following comparisons, which are not in any way specially remarkable.

No. of Station and Group	Geodetic Latitude	Geodetic Longitude	Co-latitude Geodetic / Astronomic	Astronomic	Diffce. $\lambda_o - \lambda_c$	Variation in Group
	° ′ ″	° ′ ″	° ′ ″	″	″	″
XXXII	19 1 30·43	77 39 44	70 58 29·57	38·39	− 8·82	+ 0·20
XXXIII	2 52·09	46 2	57 7·91	17·23	9·32	− ·30
XXXIV	9 33·24	43 28	50 26·76	35·65	8·89	+ ·13
XXXV	7 23·72	37 14	52 36·28	45·33	9·05	− ·03
Somtâna Group	19 5 ...	77 41 ...	70 54 ...		− 9·02	...
XXXVI	20 41 32·82	77 35 13	69 18 27·18	37·76	−10·58	+ ·61
XXXVII	44 26·93	38 59	15 33·07	44·46	11·39	− ·20
XXXVIII	44 14·73	44 10	15 45·27	56·66	11·39	− ·20
XXXIX	48 18·55	38 21	11 41·45	52·83	11·38	− ·19
Badgâon Group	20 44 ...	77 39 ...	69 15 ...		−11·19	

(4.) I turn now to the other part of my subject. And here I find it advisable to guard against a not unlikely misconception of the aim and object of such operations as are now to be described.

Longitude-difference: possible misconception of the object in view.

(5.) With few exceptions, and those of quite modern date, determinations of longitude-difference by astronomical methods have had for their object the longitude of points either geographically undetermined or only approximately known; that is to say, the object has been *geographical*. This is the case wherever the extremities of the line of operations have been unconnected by triangulation. Where such triangulation exists the difference of meridian is known thereby with much greater accuracy than any astronomical methods not of the highest order of precision can approach. The extension of the electric telegraph has greatly simplified the problem in certain respects, and *for the purpose above-mentioned* has made the operation a really easy one. But that purpose is in no respect the one in view at present. The Trigonometrical Survey of India has long since mastered the geography of India, although it has been unable to place India correctly on the map of the world. That has been done with considerable accuracy by the Astronomers of Madras; and will no doubt be done with still greater precision by telegraphic determination of longitude-difference from Greenwich. Still that is not the present object.

The object *not* geographical.

(6.) It is not very easy to say what *is* the object but, speaking generally, it may be said to be to *try* whether the Earth's form has been correctly surmised by those Geodesists who, having compared the curvatures of different meridians (as obtained by measurements of degrees of *latitude*) with each other, concluded that the meridional sections are not all alike and that the Earth's form is not, as had been assumed, a spheroid of revolution with a *circular* Equator, but a spheroid with perhaps an *elliptical* cross section. It is obvious that here we have need of an order of accuracy far greater than would suffice for geographical purposes.

General notion of the real purpose.

(7.) It seems necessary to insist somewhat on the distinction here drawn, as in all the accounts of the operations of this description to which I have had access—with certain exceptions in which the object is avowedly that which I have just mentioned—there is an undisguised faith in the overpowering simplicity of the method which cannot fail to raise the question where is the difficulty? It will perhaps be sufficient to reply, that in the exceptions to which I have alluded the whole tenor is one of exhaustive research into minute causes of error—that every effort is made to eliminate or hunt them down—in order that the result may bear close comparison with trigonometrical measurement.

Reasons for insisting on the distinction.

(8.) With so much of preface I may proceed to indicate the principal features of the first attempts to put into practice the Telegraphic Method in India.

(9.) The Equipment consists of two superb-looking transit instruments of 5 inches aperture and 5 feet focal length, constructed under the superintendence of Col. A. Strange by Cooke and Sons of York: of two astronomical clocks by Frodsham and of two chronographs by Secretan and Hardy of Paris besides relays and batteries.

Equipment

(10.) To describe all these in detail would extend this report to too great length. I will therefore only indicate the main features as they gradually presented themselves to me as requiring especial attention. For I ought not to omit to state that I came to the task profoundly ignorant of all details and more especially so in regard to the proper management of electro motive force, with which I had never had any practical acquaintance. Practice and incessant study of the subject have done much to remove the innumerable difficulties which were encountered from first to last; but I am not ashamed to own that to the very last there remained, in the management of the chronographic record especially, a considerable amount of uncertainty.

Description of instruments confined to particular features.

(11.) I have thought it best hitherto to speak in the first person, so as not to involve my colleague, Captain Campbell, in any of the statements I might make; but he will, I feel sure, bear me out in what I have just said as to the difficulty of securing satisfactory chronographic record.

(12.) The source of these difficulties is to be found in the fact that the record consists of a mark made on the revolving drum and paper by the passage of an electric spark of high tension generated in a Ruhmkorff's coil by the interruption of a strong galvanic current, which is, so to speak, the second of three links in the chain of agency between the clock or observer and the drum. We have first the line or Daniell current, broken at will by the observer; its cessation breaks the local or Bunsen circuit and current; the interruption of the latter induces in the Ruhmkorff coil the statical electricity whose discharge by spark upon the paper burns the required mark. But in order that all this may happen, not only must the whole of the apparatus be properly adjusted, but the Bunsen current must be strong enough to induce a strong spark, and the spark must find its way through paper of exactly the requisite degree of dampness. That the paper may be always properly damp it must be prepared with a deliquescent, and the degree of impregnation with the latter must depend on the hygrometric condition of the air. Here at Bangalore we are at the mercy of changes of wind which set calculation at defiance; paper that will do well enough in the early part of the evening may be almost dripping or as dry as a bone a few hours later. Accordingly I found it necessary at last to have variously prepared papers at hand to suit different weathers.

Principal source of practical difficulties to be found in the dependence on frictional electricity.

And on the proper hygrometric conditions of the record paper.

(13.) But perhaps the Bunsen battery is the most troublesome and provoking source of failure. There are about a score of tricks which it has, any one of which will impede its action or obstruct it altogether. Sometimes when it is out of temper it will play 2 or 3 of these at once, and an hour or more will be wasted in the attempt to force or coax it to behave. Lastly, there is always more or less uncertainty *which* is in fault, the relay, the battery, or the paper. As I say, to the last I never could guarantee a satisfactory record; and it is not surprising therefore that at first, with many other difficulties unexplained, the finest nights were often the ones when least seemed to be done.

The Bunsen battery a source of trouble, due to inconstancy.

Behaviour of the clocks.

(14.) Of the Clocks I have nothing but good to say.

Of the Chronographs.

15. Of the Chronographs—one is a miracle of regularity, and deserves the highest commendation. The other is very provoking.

Relays.

(16.) The Relays have done their duty creditably, but they are I think of bad pattern and ought to be changed I cannot explain their defects here.

Precise causes of failure always uncertain because of their variety.

(17.) I have here merely glanced at the different sources of trouble. As a rule they are not such as can be removed before hand; partly because their causes are but little understood, partly because they arise from and in the actual working, by expenditure of material, by the action of chemical products of that expenditure, or by change of weather. They are matters of detail individually, but each has a more or less direct and important share in the whole, and they are rarely all absent at once.

Combined action of two independent operators also necessary for complete success.

(18.) Lastly, I may add on this subject that where the united action of two otherwise independent observatories is essential to the success of a particular class of operations. the chances of miscarriage are greater than if one only is concerned.

Chronographic determinations of longitude considered with reference to demand on public telegraph lines.

(19.) For the determination of longitude-difference chronographically there appear to be two distinct classes of method, in which one clock, and two, respectively, are used. I am not prepared to enter fully into the subject of their respective merits here, further than is requisite to explain the demands upon the Telegraph Department for the use of the public wires. But it is necessary to take into consideration that the transmission

of a telegraphic signal represents a certain lapse of time, the neglect of which would involve an error—depending of course on the distance—equivalent perhaps to an error of measurement of 1 foot in 5 miles. Consequently any method which leaves this out of consideration depends in fact on others which do not; for the interval of lost time must be computed from an assumed velocity.

Transmission lapse equivalent to 1 foot in 5 miles.

1°. If one chronograph only is used, the distant signals *must* be transmitted to it, and must arrive late, and the error in question occurs. 2°. If two chronographs are used—and still one clock—observer's signals are transmitted to the clock station, arriving late, and clock signals are sent to him, also arriving late, and therefore making *his* signals appear too early. This combination therefore—of one clock and two chronographs—provides for the transmission-lapse. In both the cases mentioned however, it is to be noted that the line-wire is required during the whole duration of the *transits* at one—the distant—station. 3°. If two clock's are used one at each station, their errors and rates may be ascertained independently, by any number of stars and to any degree of precision, without leading to a knowledge of longitude-difference. But no sooner is any signal *timed* by both—being transmitted for the purpose by the line-wire—than the clock—difference is known (subject as before to the delay in transmission) and hence the longitude-difference. The direction in which the signal is sent will determine whether the clock difference is too small or too great on account of the delay and by sending alternately the excess and defect (if equal) become known. With two clocks therefore, and two chronographs, all that is required of the wire is to transmit "comparison signals:" the rest is local work. It is obvious however that as the latter equipment includes the former, and with it the power of employing the methods which are suitable to it, the full equipment gives the choice of the 3 methods, two of which employ the line largely, and the 3rd only at intervals of two or three hours.

Method where two clocks are used.

(20.) The quantity to be found being not an *absolute time*, but a *difference of times*, it is not necessary to know exactly the actual clock errors, but the difference of these. This is a very important point—which does not seem to have been taken advantage of in either of the few continental operations of this kind which I have been enabled as yet to procure. As the whole of our regular work has been based upon it to that extent over-riding such precedent as we have—I must extend this portion of my subject to explain the reasons for adopting it. The best way to do so will be to give our actual system and the process by which it is proposed to deduce the longitude-difference.

Absolute time not required; only difference of times.

(21.) Clock comparisons are exchanged at 8-30, 10-30, 12-30, P.M. Between these hours transits are taken "locally" at such times that *the same sets of stars are observed at both stations*, as far as circumstances permit. Certain intervals are arranged for taking instrumental errors of adjustment; and that is the whole of the programme.

Ordinary programme.

The reductions may be outlined thus:—comparisons give *clock differences* and *transmission lapse*: selections from the transits give rate of each clock, and therefore clock-difference at any time other than that of comparison: [or if the comparisons are sufficient, the difference at any intermediate time is known from them alone. It is an open question which method will be best, in this respect.] Transit of *any* star over both meridians gives two clock times whose difference equals the clock difference at the moment of transit over the E. meridian + longitude-difference + effect of rate of W. Clock during the interval from one meridian to the other. The only unknown quantity here is the longitude-difference, which is therefore determined from this equation. Every star observed at *both* stations gives thus a measure of the required longitude-difference, without any regard to its precise R. Ascension at the time, to find which would require a large amount of really unnecessary labour. For it is to be remarked that the only way in which *actual* (as distinct from relative) time or rate enters in the final expression of longitude-difference is in the adopted value of rate-effect during the passage of a star from one meridian to the other a minute quantity, not liable to sensible error, which *must* enter in any case, whatever the system or treatment.

Rationale of reductions.

(22.) I am at a loss to account for the non-appearance of this view of the matter in any practical shape, in the publications to which reference has been made; for the principle which underlies it is certainly sound. It is possible that, collaterally, knowledge of stars' places is advanced, and that longitude *alone* is not admitted to be the sole object in view. And no doubt it is contrary to general principles to proceed by selection from observations to obtain that which might be made to depend upon all. It is however to be remarked that the use of the chronograph makes a vast difference in the application of such principles. The reason for not discarding observations actually made has some reference to the labour of making them. The chronograph gives us the means of obtaining a large mass of *available* record with very little more trouble than is required for a small quantity and it is

Reasons for adopting a method not generally practised.

at this stage—before the real labour begins—that the selection may be made. It is in the *reading off* of the chronographic record that we must look for reasons for or against the utilization of all or only some of the available material.

Anticipation of some results.

(23.) My departure on furlough while a considerable portion of such material remains still unworked, prevents me from doing more than hazard a few numerical results; which my colleague Capt. W. M. Campbell, R.E., will no doubt be able in due time to present in a more satisfactory form. I should not however be acting fairly towards him, considering the large amount of work to be done before a full report can be looked for—either in thus deserting him or in anticipating the conclusions at which he may arrive—but for the fact that my taking furlough last year was deferred only for the sake of commencing this work, and that I am now enabled to leave the prosecution of it in worthy hands.

Flexure of one of the telescopes supposed to detract from the value of the operations.

(24.) There is one respect in which there is unhappily grave reason to suspect any appearance of accuracy which the results may hereafter present. Owing to some cause which has completely baffled detection, it is almost certain that the liability of the tube or axis of one, and perhaps of the other, of the two transit telescopes to lateral flexure is very considerable. This is a very common failing in large instruments, I believe, but at the same time one very apt to be overlooked owing to the great difficulty of proving satisfactorily its existence. Of course it is still more difficult to investigate and allow for it. If it exists to the extent to which my experiments point it will I fear be necessary to take the fact largely into consideration.

Personal equation determined conclusively.

(25.) Very careful observations have been made for the determination of our relative personal equation, with results which I have reason to believe highly satisfactory. There is nothing to be apprehended on this score.

Clock comparisions supply evidence of first rate performance

(26.) The comparison of clocks at Mangalore and Bangalore have been all read off, reduced and collated for the purpose of determining clock-difference, relative rate, and transmission-lapse. The results are both satisfactory and suggestive. The extreme *change* of relative rate shown would amount if continued to only 0″·17 per diem; but being undoubtedly only an exaggerated differential change due to a regularly repeated daily oscillation, it is probable that ± 0″·08 per diem more correctly represents the range of *accidental* variation, at the times of comparison. This gives a high character to the clocks. The transmission-lapse, or retardation of the delivery of the signal is still more remarkable, but less easy to understand. Whatever be its value, it consists of two distinct elements, viz:, the delay on the line, and the delay at the magnet. From the nature of the comparison the latter is present in both circuits—the local clock circuit and the distant clock circuit—and if to a like extent, the effect is eliminated in the comparison; and the delay on the line is alone visible in these. But such a condition would be accidental: theoretically there must be a retardation peculiar to each relay, and its adjustment, and strength and direction of current passing through it; and it is the difference of these retardations—more correctly the excess of that belonging to the line-relay and current over that belonging to the local relay and current—which will tend to swell the total. Instead of an excess there may be a defect in which case the line retardation may be reduced in amount if not negatived. It is certain that the magnetic force is more effective with a current in one direction than another. We have here then all the elements of diversity necessary to produce a varying total retardation and as a matter of fact we do find the following values, the distance being 245 miles.

Transmission-lapse or retardation of delivery presents extraordinary features.

		CURRENT.	
		Positive	*Negative*
Singals from	E.	0″·028	0″·003
„	W.	·022	·011

These depend on a sufficient number of independent determinations to leave no doubt whatever that they must be explained in some such way as indicated. The mean of the four would I conceive be free from every kind of *error* and would presumably be slightly in excess, if any thing, of the true retardation *along the line*. Its value, ″·018, gives a velocity of 13,600 miles per second, which is double the value generally assigned.

Velocity of transmission seems to be twice as great as determined in other similar operations.

(27.) It is hardly necessary to say that the worth whatever it may be, of the primary operations is not in the least affected by a collateral issue such as this. But it shows very unmistakeably that there may lurk small constant lapses of time in apparent instantaniety, which require very close looking after.

(28.) I have thought it unnecessary to enter into many details of time place and season, in this report, because from beginning to end, though the *venue* was changed ostensibly with a view to obtain local determinations of longitude-difference, the real object was and could be nothing more than *practice*—with such ultimate fruit as successful or unsuccessful prosecution might haply produce. In this matter one is wholly dependent on coincidence of a variety of conditions, and geodesy must stand aside if these are not convenient. Thus Bangalore and Madras were in every way suitable—and Mangalore was a convenient extension of the arc although whether in part or as a whole, it is of very little consequence to geodesy whether the determination is good or bad. It is a short arc, across a peninsula, incapable of extension, and unrepresentative (owing to medial table land) as a part of the normal figure and cannot be accepted as such without large reservation. But the presence of the Telegraph, the Railway, the Triangulation, and the absence of the ordinary waste of time and trouble and money in marching and camping in strange countries, made it certainly an expedient selection for a trial campaign.

Comparative worthlessness of the present arc from a geodetical point of view counterbalanced by practical advantages as an arc of experiment.

Extract from the Narrative Report—dated 19th September 1873—of Captain W. M. CAMPBELL, R.E., Deputy Superintendent 3rd Grade, in charge Astronomical Party No. 2.

In my narrative report for season 1871-72, dated 14th August 1872, I was unable to give any of the results of my work, *viz.* the determination of Latitudes on the Mangalore Meridional Series, because the reductions at that time were not nearly completed.

(2.) I have already informed you, that as these reductions were brought near completion, a startling difference was found between the results by N. and S. Zenith stars respectively: the co-latitude given by the former, being always in excess of that derived from the latter, or in other words, the instrument measures all Zenith Distances in excess of the truth.

"N—S difference" Zenith Sector No. 1.

This fault will be spoken of as the "N—S difference." A similar difference has been found in other instruments, notably in one of the Astronomical Circles lately in use, in which case it increased to so serious a quantity that the instrument was laid aside.

The sister Zenith Sector, used by Captain Herschel during three field seasons, shows hardly any trace of "N—S difference," season 1869-70 giving, N—S = —0″·09 and season 1871-72, +0″·29.

The difference given by Zenith Sector No. 1 has features which, so far as I know, have not been found in other cases of the same kind. The Astronomical Circle measured Zenith Distances in defect of the truth, the amount of error being subject to no law that could be traced.

Zenith Sector No. 1 measures Zenith Distances in excess of their true value, and the most superficial examination shows that the error is a function of the Zenith Distance, being nearly exactly in direct proportion to it.

This law has been taken advantage of, and a set of corrections computed for each station, the application of which bring the results into as close accordance as could be wished for.

Attempt to correct results for "N—S difference."

The method employed was the following:—

It was assumed that the error of each Zenith Distance measured, was C. Sin Z. D., C being a constant for each station, which was computed by the simultaneous solution of a set of equations, one for each star, of the form

$$M + C. \text{ Sin } a - A = 0.$$

in which A is the observed co-latitude by the star whose Zenith Distance = a, (N.Z.D. being + and S.Z.D. —) and M is the most probable value of co-latitude by all stars.

(3.) The accompanying tables give abstracts of the results at all stations, showing the effect of the application of these computed corrections, with other particulars.

It will be observed, that no alteration in the position or use of the instrument appears to affect the "N—S difference," and all comparison of the results seems to lead to the conclusion, that this difference will not affect final results obtained from an equal number of north and south stars, of nearly equal mean Zenith Distance. Still less might it be expected to affect the result of observations of pairs of north and south stars, but unfortunately that system involves the use of stars, whose places are not known with the degree of accuracy desirable, besides other disadvantages.

Effect of "N—S difference."

(4.) In table II the effects are shown, 1st of the reversal of the instrument on its pier, and 2nd of the order of Face-observation followed, and these are separated into two sets *viz* : those belonging to the three stations at which the reversal of the Sectors with reference to the microscopes was carried out, (see para. 26 of my last year's report) and of the others, at which this change was not made.

Effect of reversing the Zenith Sector.

So far as can be judged this reversal of Sectors appears to be useful, but the number of cases is so small that the result may be merely fortuitous.

(5.) In table III, different values of the general mean co-latitudes are arrived at, by combining the means given by several pairs of sets of observations. The mean of these values is what I should adopt as the final value, (unless indeed the proposed correction of the observed results is allowed, in which case I should prefer the value so obtained to any other) and it is taken out at the foot of the table and compared with the Geodetic Latitude for each station.

Adoption of final results.

This comparison shows a relative northerly attraction, with reference to the origin of Geodetic Latitudes, *viz* : Calcutta, at every station except Mangalore, where the opposite obtains in a slight degree. About Hunawali and Koramoragúda, the topography of the country strongly points to the probability of attraction such as these results show, because these stations are near the verge of the Mysore plateau, where there is a precipitous descent of fully 2,000 feet to the low country of Kanara. The result at Mangalore, on the contrary, is the reverse of what might have been looked for.

Apparent deviation of plumb-line.

(6.) A disagreeable feature in these results is the discrepancy between the two values of the co-latitude of Kundgorl, amounting to 0″·23, but this is capable of a certain amount of explanation.

Discrepancy between two sets of observations at Kundgorl.

During the first set of observations at this station the position of the instrument was the same throughout, and is believed to have been that known as "Azimuthal Stud North," and the Sectors were not reversed. Now at four other stations where the Sectors were not reversed, the mean difference between the results obtained with Azimuthal Stud North, and South, was 0″·13, North being in excess of South, and if half of this quantity be considered as a correction to the result in either position, and applied to the first value obtained at Kundgorl, the discrepancy becomes 0″·23—0″·07=0″·16. Very little faith can be put in this mean difference of 0″·13 as it is derived from only four values, so discordant as to give a *p. e.* of their mean= ±0″·17, actually greater than the quantity itself, but it affords a plausible explanation of the otherwise startling discrepancy under notice. For many reasons the second value of Kundgorl is much to be preferred to the first.

(7.) The stars used throughout season 1871-72 were selected with reference to both the Greenwich seven-year Catalogues of 1860 and 1864, and their places depend on a mean number of observations of 26 and 19 in these catalogues respectively. The places adopted were the means of the two catalogue values, weighted according to the number of observations belonging to each. Of 96 stars common to both catalogues and reduced by each to January 1, 1872, the mean difference of resulting N. P. D. was 0″·16—that from the catalogue of 1860 being the greater.

Selection of stars.

TABLE I.—ABSTRACT OF RESULTING CO-LATITUDES

as observed, and as treated for "N−S difference"—Season 1871-72.

STATION.	North Stars		South Stars		Mean Co-latitude as deduced from observation					Mean Co-latitude after correction for N−S					General Mean Co-latitude		Diff. $\frac{N+S}{2} - \frac{n+s}{2}$	Diff. of Mean Z.D. A−B	By computation M and Log. C
	No.	Mean Z.D. A	No.	Mean Z.D. B	Mean by N. Stars N	p.e.	Mean by S. Stars S	p.e.	Diff. N−S	By N. Stars n	p.e.	By S. Stars s	p.e.	Diff. n−s	Observed $\frac{N+S}{2}$	Corrected $\frac{n+s}{2}$			
		° ′		° ′	″		″		″	″		″		″	″	″		° ′	″
Majala Co-lat.	22	5 29	22	5 30	5·635	±·112	3·671	±·073	+1·964	4·653	±·070	4·656	±·071	−0·003	4·653	4·655	−0·002	−0 1	4·66 1·0132
Mawilhunda Co-lat. 73 34	19	5 56	19	5 52	56·749	·148	54·326	·106	2·423	55·528	·068	55·533	·080	·005	55·537	55·531	+·006	+0 4	55·53 1·0737
Naolur Co-lat. 74 34	16	6 13	16	6 19	32·938	·163	30·121	·088	2·817	31·536	·076	31·548	·046	·012	31·530	31·542	−·012	−0 6	31·54 1·1133
Kundgorl Co-lat. 74 44	23	5 54	24	6 15	46·642	·139	44·800	·108	1·842	45·744	·080	45·749	·062	·005	45·721	45·746	·025	0 21	45·75 0·9421
Kundgorl 2nd Visit	16	6 29	16	6 31	46·826	·159	44·134	·124	2·692	45·478	·079	45·489	·086	·011	45·480	45·484	·004	0 2	45·48 1·0780
Hunawali Co-lat. 75 43	15	6 2	16	5 28	30·351	·110	28·428	·097	1·923	29·337	·069	29·343	·060	·006	29·390	29·340	+·050	+0 34	29·34 0·9843
Koramoragúda Co-lat. 75 51	15	5 6	16	5 31	59·263	·126	57·477	·130	1·786	58·399	·116	58·407	·077	·008	58·370	58·403	−·023	−0 25	58·40 0·9865
Mangalore Co-lat. 77 7	22	5 45	22	6 13	43·039	·112	41·278	·128	1·761	42·190	·065	42·196	·074	·006	42·159	42·193	·034	0 28	42·19 0·9291

The mean *p.e.* of $\frac{n+s}{2}$ for all stations is ±″·052, the mean number of stars per station being 37.

Using Zenith Sector No. 2 at 6 stations in Season 1869-70, Captain Herschel's resulting co-latitudes gave an average *p.e.* = ±″·049, his mean number of stars being 55.
These results agree closely, as might be expected supposing the treatment of the observed quantities of Sector No. 1 to have eliminated the effects of the "N−S difference" of that instrument.

TABLE II.—ABSTRACT OF RESULTING CO-LATITUDES

from observations taken in different ways—Season 1871-72.

No.	Station.	By observations taken with Instrument in opposite positions.									By observations taken with different order of Faces.								
		Azimuthal Stud North.				Azimuthal Stud South.				Diff. $\frac{a+b}{2}$ minus $\frac{c+d}{2}$	Face East, face West.				Face West, face East.				Diff. $\frac{p+q}{2}$ minus $\frac{r+t}{2}$
		By N. Stars a	By S. Stars b	Diff. $a-b$	Mean $\frac{a+b}{2}$	By N. Stars c	By S. Stars d	Diff. $c-d$	Mean $\frac{c+d}{2}$		By N. Stars p	By S. Stars q	Diff. $p-q$	Mean $\frac{p+q}{2}$	By N. Stars r	By S. Stars t	Diff. $r-t$	Mean $\frac{r+t}{2}$	
				(N−S)				(N−S)					(N−S)				(N−S)		
		"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
1	Majala ...	5·66	3·86	+1·80	4·76	5·18	3·25	+1·93	4·22	+·54	5·70	3·92	+1·78	4·81	5·36	3·32	+2·04	4·34	+·47
2	Mawinhunda* ...	56·74	54·44	+2·30	55·59	56·89	54·24	+2·65	55·57	+·02	57·11	54·41	+2·70	55·76	56·63	54·27	+2·36	55·45	+·31
3	Naolur* ...	32·96	30·23	+2·73	31·60	33·15	30·06	+3·09	31·61	−·01	33·12	29·85	+3·27	31·49	32·95	30·33	+2·62	31·64	−·15
4	Kundgorl ...	Observns. taken in one position only, believed to have been "Azimuthal Stud N."									46·85	44·92	+1·93	45·89	46·45	44·64	+1·81	45·55	+·34
5	Ditto * ...	46·85	44·11	+2·74	45·48	46·79	44·18	+2·61	45·49	−·01	46·73	44·21	+2·52	45·47	46·93	44·08	+2·85	45·51	−·04
6	Hunawali ...	30·25	28·29	+1·96	29·27	30·44	28·61	+1·83	29·53	−·26	30·90	28·84	+2·06	29·87	30·08	28·08	+2·00	29·08	+·79
7	Koramoragúda ...	59·45	57·41	+2·04	58·43	59·07	57·34	+1·73	58·21	+·22	59·18	57·62	+1·56	58·40	59·36	57·22	+2·14	58·29	+·11
8	Mangalore ...	43·11	41·20	+1·91	42·16	42·90	41·40	+1·50	42·15	+·01	42·90	41·25	+1·65	42·08	43·16	41·29	+1·87	42·23	−·15
	Mean Difference due to position of Azimuthal Stud $\left(\text{or } \frac{a+b}{2} - \frac{c+d}{2}\right)$ ...									+·007	Mean difference due to order of observation $\left(\frac{p+q}{2} - \frac{r+t}{2}\right)$ ...								+·21
	At Stations (1) (6) (7) (8) ditto ...									+·13	At Stations (1) (4) (6) (7) (8) ditto ...								+·31
	Ditto (2) (3) (5) ditto ...									·00	Ditto (2) (3) (5) ditto ...								+·04

* At Stations (2), (3) and (5) only the reversal of the Sectors with reference to the Microscopes was introduced.

TABLE III.—ABSTRACT OF RESULTING CO-LATITUDES.—*Season* 1871-72.

Method of arriving at General Mean Co-latitude.				Majala 73° 13′	Mawinhunda 73° 34′	Naolur 74° 34′	Kundgorl 74° 44′	Kundgorl 74° 44′	Hunawali 75° 43′	Koramo-ragúda 76° 51′	Mangalore 77° 7′
				"	"	"	"	"	"	"	"
(1)	Observed Mean by North Stars	$= N$	$\frac{N+S}{2} =$	4·653	55·537	31·530	45·721	45·480	29·390	58·370	42·159
	Do. South Stars	$= S$									
(2)	Corrected Mean by North Stars	$= n$	$\frac{n+s}{2} =$	4·685	55·531	31·542	45·746	45·484	29·340	58·403	42·193
	Do. South Stars	$= s$									
(3)	Mean of all observations azimuthal Stud North	$= A$	$\frac{A+a}{2} =$	4·490	55·580	31·605	...	45·485	29·400	58·320	42·155
	Do. do. Stud South	$= a$									
(4)	Do. Face order E.W.	$= B$	$\frac{B+b}{2} =$	4·575	55·605	31·565	45·720	45·490	29·475	58·345	42·155
	Do. do. W.E.	$= b$									
(5)	Do. Zeros about 0°	$= C$	$\frac{C+c}{2} =$	...	55·506	31·464	...	45·510			
	Do. do. 180°	$= c$									
Means of all the above omitting (2)				4·573	55·557	31·541	45·721	45·491	29·422	58·345	42·156
Do. Latitudes $= A$				55·427	4·443	28·459	14·279	14·509	30·578	1·655	17·844
Geodetic Latitudes $= G$				59·271	6·666	33·673	17·793	17·793	35·009	9·116	17·248
Difference $A - G$				−3·844	−2·223	−5·214	−3·514	−3·284	−4·431	−7·461	+0·596

The Geodetic Latitudes here given for Majala, Mawinhunda, Naolur and Kundgorl, are those given in the "Preliminary chart of the Mangalore Meridional Series" corrected by + 4″·16. Those of Hunawali, Koramoragúda and Mangalore, have been supplied by Major Branfill Deputy Superintendent in charge Madras Party.

N.B. Hunawali and Koramoragúda are the same points as Major Branfill's Húnavalli H.S. and Koramúr H.S.

Field Season 1872-73.

(8.) During the past Field Season, I have been associated with Captain Herschel in the determination of differential Astronomical Longitudes by means of the Electric telegraph. Captain Herschel, who had charge of the combined operations, has lately proceeded to Europe on furlough. Before his departure he submitted a report of our work, but at that time the reductions were not far enough advanced to enable him to give any Longitude results, and his report was less full in many respects than it probably would have been had he had more time at his disposal. In the following remarks I shall endeavour to make the general narrative of our operations more complete, and to describe the instruments used, in such detail as may appear necessary. I hope also to be able to give at least some idea of the results obtained.

Description of Instruments.

(9.) The instrumental equipment consists of two complete sets, each set comprising: a Transit Telescope, a Chronograph, with accompanying electrical apparatus, and an Astronomical Clock.

Transit Instruments.

(10.) The Transit Telescopes are by Cooke and Son of York, sister instruments known as No. 1 and No. 2, of nearly identical dimensions. The focal length is slightly over 5 feet, and diameter of object glass 5 inches, the whole of which is effective. There are two wire diaphragms one of which carries a single vertical and a pair of horizontal wires, the latter about 1′ apart. The other a set of 25 vertical wires arranged in groups of 5 each. The latter is worked by a micrometer screw, and the former may be called fixed although a screw is provided for adjusting its position as required. (Each instrument has two "Eye Ends" precisely alike, except that the micrometer diaphragm of one has only the usual set of 5 transit wires, being intended for "Eye and Ear" Observations.)

The 25 vertical wires were conveniently named A, B, &c. to Y, the centre one being M. Their mean distance apart is $36^s{\cdot}6 = 2^s{\cdot}44$ equatorial seconds, and the groups are separated by double intervals.

Micrometers of Transit Instruments.

The micrometers have double heads, one graduated to show revolutions and the other for divisions, the two being connected by a set of toothed wheels. The value of a revolution was found to be so nearly identical in the two instruments, that a mean value has been used for both, *viz.*: $1^R = 33^s{\cdot}75$, which is nearly exactly equivalent to 100 revolutions per inch of screw. The micrometer head is protected by a cap, which being screwed on after setting to a particular reading, insures it against being accidentally disturbed. There is a small window of talc through which the setting can be inspected. A screw is provided for rapidly traversing the eye piece during observations, so that the star may be kept close to the centre of the field. The plate carrying the wire diaphragm is capable of adjustment for verticality of wires.

Eye pieces of Transit Instruments.

The set of eye pieces comprise direct eye pieces of various powers, with prisms for oblique use, and a Bohnenberger eye piece for use with the mercury trough. The latter has been used throughout for all observations, that of No. 1 instrument is much superior to that of No. 2, both in construction and magnifying power, the former being about 160 and the latter not more than 80.

Setting Circles.

There are two setting circles attached to the tube of the telescope, each 7½ inches in diameter, graduated to 20 minutes and reading to 1 minute by verniers, and each provided with a coarse level. They are not fixed but can be turned round and clamped in any position, which admits of adjustment for setting by declinations direct, or by Z. Distances &c. There is no means of clamping the telescope when set.

Wire illumination.

(11.) Two kinds of wire illumination are provided:—1*st*. The ordinary dark wires in bright field—2*nd*. Bright wires in a dark field, the arrangement being as follows. In the cube of the axis (see para. 12) there is a light plate revolving on an axis at right angles to both telescope and transit axes, (cut out in the centre so as not to interfere with rays from the object glass) and capable of being moved through an arc of 45° by a rod with a handle projecting close to the eye piece.

A lamp is placed opposite one end of the transit axis, which is perforated. When the plate is inclined at 45° to the transit axis, the light from the lamp is reflected directly on to the wires by a small black glass reflector, placed in the centre of the opening in the plate; *i.e.*, approximately at the intersection of the transit and telescope axes. When the plate is turned so that its plane coincides with the transit axis, the light is intercepted by a set of four prisms and reflected downwards, between the telescope tube and an inner tube provided for the purpose, the four sets of rays converging slightly, so as to strike upon four prisms attached to the frame carrying the wire diaphragms, two on each side, and slightly above the plane of the wires. The latter prisms again reflect the light at right angles so that the rays are now nearly in the plane of the wires, which thus become illuminated by the rays from the prisms on each side, the field remaining dark. Both kinds of illumination are fairly satisfactory.

The object glass is fixed in its cell, so as to be pinched at three points only, and the cell, instead of being screwed into the telescope tube, has close contact with it only at three points where it is attached by three screws, and these are equidistant, so that the object glass may be put on in three different positions.

Object glass fittings.

(12.) The frame of the telescope consists of three principal pieces, *viz.*: the axis, the object-half, and eye-half, which pack for travel separately.

Frame of Transit Telescope.

The shape of the axis is a central cube of 9½ inches side, supported by conic frustra 9¼ inches in diameter at junction with cube, and 9¾ inches axial length, tapering to 3 inches diameter and terminated by enlarged cylindrical shoulders 3¾ inches diameter and 2¼ inches wide, into which lastly the steel pivots are fixed, the axis having I believe been shrunk on to them. The pivots are 1·9 inches diameter perforated by an opening 0·9 inch diameter, and they project 1·9 inches from the axis shoulder. The total length of axis is thus 37·3 inches, and 33·5 inches between shoulders. It weighs about 65 lbs. and the thickness of the metal is about 0·37 inch throughout the cube and cones, which were cast in one piece, the cube being strengthened by ribs. The conical parts were turned both inside and out to insure as perfect symmetry as possible.

Axis.

Of the four faces of the cube parallel to the axis, one pair are perforated by openings of 3¼ inches diameter for collimation observations. They can be closed with caps and are crossed by spokes which support the illuminating plate. The other pair are cut out with openings of 6·8 inches diameter for the attachment of the telescope half tubes, with an annular space 0·6 inch wide outside, turned down about 0·07 inch or 0·08 inch below the surface.

(13.) The two halves of the telescope are each attached to the axis by 12 powerful steel bolts, which pass through a flange at the base of the tube, ¼ inch thick and projecting 0·7 inch, and screw into the metal of the cube which is 0·37 inch thick. The tubes are farther steadied by circular flanges projecting about 0·07 inch and fitting into the annulus outside the opening in the cube. The two half tubes are quite plain except that about 1½ inches from their bases, arms are cast upon them to support levels, to which I shall allude below. The object half is about 2 feet 8½ inches long from axis to outer surface of object glass, and weighs (with dew caps 6 inches long but without levels) 32 lbs.

Telescope tube.

Object half tube.

The eye half tube is only 1 foot 10¾ inches long from axis to where it is cut off for the attachment of the "eye end" (of which there are two, *vide* para. 9) by four brass screws. The "eye end" is composed of two concentric tubes to allow of the focussing adjustment, (which is performed by two opposing screws acting on a stud) it is 6 inches long measured to the plane of the wires, 3¾ inches diameter and weighs 6 lbs. The weight of the eye half altogether (without levels) is 40 lbs. The total weight of the telescope is thus 65 + 32 + 40 = 137 lbs.

Eye half tube.

(14.) Each telescope was intended to have a set of four hanging levels, but No. 2 was sent out before they were ready, and the level bubbles provided with No. 1 are of very inferior quality.

System of Levels of Transit Instruments.

When horizontal collimators, and the mercury trough (or vertical collimator) are used together, levels are not necessary, and thus it happens that these levels have never been used during the observations with either instrument. No detailed description therefore seems called for at present, but as the system is quite novel a few particulars will not be out of place. Close above and below the cube of the axis, brackets are cast on the telescope tube carrying four arms, to which again the levels are suspended on spindles, the arms being long enough to allow the levels to revolve freely on their spindles as the telescope is rotated, always maintaining a position, if in adjustment, at right angles to the plane of revolution of the telescope.

The system has certainly advantages over the usual hanging or striding level:—1st. There are four levels in place of one—2nd. They can be read in all positions of the telescope—3rd. They are affected in the same degree as the telescope by axial flexure and by irregularities of pivot.

Advantages.

On the other hand they have objectionable features, the principal of which are:—

1st. Irregularities of figure of the spindle bearings, on which the levels hang, will affect the levels in the same way as irregularities of pivot figure, but in a much greater degree, because these spindles are only 10½ inches long, whereas the axis is above 30 inches. 2nd. The adjustments are very numerous and troublesome, and the effect on the level readings of residual error in the adjustment of the arms, varies with the position of the instrument. These arm adjustments are of two kinds and their effects vary as the sine and cosine of the altitude respectively. Considerable experience of the system (furnished with better level bubbles than we now possess) is required, before an opinion of its value can be arrived at.

Disadvantages.

(15.) The pivots rest in nearly semi-cylindrical bearings of gun metal, of their own length and diameter, but cut away in the lower part so that there is contact only on two arcs of about 60° each.

Pivot bearings.

The under surface of these bearings is spherical, fitting exactly the upper surface of the beds on which they rest, and to which they are attached by a bolt passing through a slotted hole, so that the whole forms a universal joint, which insures the equal bearing of the pivots throughout their length. Again each of these beds rests on a lower or foundation plate of iron, which lastly are placed on the masonry piers. One pivot bed has three footscrews by which the level of the transit axis is adjusted, and the other has a provision for the adjustment of Azimuth. The pivots are protected from dust by well fitting caps. The weight of each pivot bed with foundation plate is about 40 lb.

(16.) The foregoing measurements and weights are those of No. 1 telescope and do not profess to be very exact. The other instrument only differs slightly in any of these particulars, but there is an important difference in their construction, No. 2 being made of gun metal throughout, while either the axis alone or the whole of No. 1 is of aluminium-bronze.

Difference in construction of Nos. 1 & 2 Telescopes.

(17.) I have gone into great detail in the description of these instruments, because of the peculiar differences in their behaviour. The collimator readings of No. 1 are remarkably constant, and are not affected by alteration in the manner of taking them. On the other hand the collimator readings of No. 2 alter to an extraordinary extent according to the method of observation, owing to which grave doubts are thrown on the value of any determination of collimation, and to an equal degree on all work turned out with the instrument. Captain Herschel, who used that telescope during the observations for difference of Longitude, introduced a strict system of manipulation during collimation observations, admirably calculated to insure the most reliable results at the time, which will also furnish a most valuable guide for the application of corrections to the work done, in case future investigation should provide data for that purpose.

Difference of performance.

Faults of No. 2

(19.) One is naturally led to compare the behaviour of Transit Telescope No. 2, with that of Zenith Sector No. 1, having in view the possibility of tracing their faults to similar sources, and I hope that an investigation of both carried on together, may be more likely to lead to some conclusion than would be the case with either treated alone.

Faults of Transit Telescope No. 2 and Zenith Sector No. 1 compared.

(20.) In the "Monthly Notices of the Royal Astronomical Society" (*vide* February 1873 page 219) mention is made of an instrumental error found in the new Transit Circle of Cambridge Observatory, exactly similar to one feature of our Transit Telescope No. 2. It would be very interesting to know if this resemblance between the two instruments extends beyond the particular point noticed.

Similar fault found in Transit Circle at Cambridge.

I shall here quote from a memo. of Captain Herschel's on the subject, some principal points of the conclusions to which he came after an extensive series of observations with our telescope, and compare them with the facts observed with regard to the Cambridge instrument.

Some particulars of behaviour of Telescope No. 2.

Captain Herschel says :—

"Nothing is more clearly proved by every series of experiments, incidentally, than that the same object will give a different intersection reading according as the direction of previous motion (through a quarter of a circle) is one thing or the other. The reading of a horizontal collimator is 1″ greater if the telescope is brought down (*i.e.* the object glass) from the Zenith, than if it is raised from Nadir. The same difference is found very generally at the Nadir, if the telescope is turned round in different ways, the greater reading being due to a descent through the North."

Remarks by Captain Herschel.

"Provided that the general rotation is *continuous* the readings at every point are constant, except perhaps at starting. If we call the rotation through North, Zenith, South, Nadir "direct," and the contrary "reverse" and if after one or two 'direct' rotations the readings (of the North and south collimator and the mercury trough respectively) are

N S M

"then after 2 or 3 "reverse" rotations the readings will be

N + 1″ S − 1″ M + 1″

If now the rotation, ceasing to be continuous becomes oscillatory through half a circle, the element of constancy disappears, and a *progressive* change is noticeable in readings which would otherwise be reproduced, until a limit is reached regarding which there is much conflicting evidence—as to the amount, but none as to the sign. If the oscillation is through the Zenith the readings increase, and if through the Nadir they diminish; the rate of change depending on what the last condition was, being rapid if the last reading differed much from the limit. The total change is much greater in the lower than in the upper oscillation, being 4″ or 5″ in the latter to 2″ or 3″ in the former."

To this I may add, that after one kind of motion has impressed its effect on the Telescope, that effect seems to remain permanent until motion of another kind is given. The telescope shows no sign of recovering a normal position if allowed to remain at rest. Also that, in order to give the effect of any particular movement, it must be carried to a considerable extent, a quadrant at least. Now quoting from the monthly notices—

Additional features.

Particulars as to Transit circle at Cambridge.

"When the instrument is turned through the south horizon to the Nadir, the reading of the observed Nadir point is about 1″·5 in excess of that which is obtained when the instrument is turned through the north horizon to the Nadir." It is added (page 220) that after many experiments were tried to correct this error without effect—"Professor Adams fears that there is a defect at some point of the tube itself so that it yields to a certain extent and does not recover itself until its weight is brought to act in the opposite direction. If this be the case, the only cure of the evil will be to replace the faulty tube by a new one."

Chronographs.

(21.) The chronographs are called A and B, and are exactly alike. They were made by Messrs. Eichens and Hardy of Paris, the latter taking charge of the Electric arrangements.

The instruments may be said to consist of 3 parts :—

1st. The clock work for driving and regulating.

2nd. The revolving barrel carrying the paper on which the record is impressed.

3rd. The carriage carrying the recording styles.

The regulator.

(22.) The regulator, so far as I know, is of quite a novel construction. It consists of a pair of governor balls connected, by a train of toothed wheels, with a small fan revolving on a vertical spindle, at the rate of about 30 revolutions per second, inside a fixed cylinder, in the circumference of which little windows are cut for the passage of air. An outer cylinder, with a corresponding set of windows, fits closely over the fixed one, and is connected with the governor balls in such a way that, as the latter rise owing to an increase of speed, the outer windows come into coincidence with the inner and allow the air to pass, whereby the resistance offered to the fan is increased and the rate of the machine checked.

Curious difference in behaviour.

The two instruments present a curious difference in the action of this regulator. In B it never rests for an instant, the outer fan-cylinder being in a constant state of oscillation; but in A it preserves one position pretty steadily for a while and then shifts to another. This difference has always existed and its cause could not be traced by the maker himself. As might be expected, the rate of B is found to be more uniform than that of A.

The barrel.

(23.) The barrel is 11¾ inches wide and 3 feet 1·6 inches in circumference, and weighs about 45lbs. Each instrument has three spare barrels. The paper used is about 3 feet 2¼ inches long and is put on with common paste.

The style carriage, &c.

(24.) The style carriage rests on a table parallel to the axis of the barrel, and is made to travel along it by a screw which is geared with the barrel. There are two styles carried by arms which project over the barrel, so that the styles rest upon the paper, and trace a spiral thereon, progressing at the rate of slightly more than ⅛ inch per revolution. The barrel is intended to revolve once in 2 minutes; hence the whole of it is traversed by the styles in about 3 hours, and a second of time corresponds to 0·313 inch linear space. There is a third arm which can also be furnished with a style if required, but it usually carries a small sharp-edged roller, which presses on the paper and traces a line thereon. The styles terminate in rounded platinum points which should rest as lightly as possible on the paper. The arms are insulated from the metal of the carriage by a block of ebonite. The points of the styles cannot be brought nearer to one another than about $\frac{1}{6}$ inch, they are therefore adjusted to follow one another at a convenient distance apart, tracing parallel lines just so far separated as to prevent possible coincidence of the marks made. The record is made by electricity, the paper being prepared for the purpose, as will be explained.

(25.) There are several provisions for ungearing the barrel, style carriage, &c. and for raising the styles off the paper. The details of these instruments are beautifully worked out, a degree of care and attention which is not often met with in like matters, being given to the most insignificant parts.

The behaviour of B may be considered perfect, that of A is not quite so satisfactory.

The Clocks.

(26.) The clocks are ordinary astronomical 8 day clocks by Frodsham, exactly alike, with the usual arrangement for breaking an electric circuit every second, *viz:*, by a 60 toothed wheel revolving once in a minute. One tooth is cut off so that one second signal is missed, this is made to agree with 0ˢ on the dial, and thus the commencement of each minute can be traced. Table IV will give some idea of the performance of these clocks.

The method of recording by electricity.

(29.) The method of obtaining the record by electricity is as follows :—One style is always in connection with the clock, and the other is generally at the disposal of the observer, hence they will be spoken of as the "Clock Style" and "Observatory Style." Each has an electrical apparatus composed as under.

1st. A metallic circuit passes through the clock, a voltaic battery of any sort, and the coils of a relay, the armature of which is acted upon by a spring, so that it is drawn away from the "contact stud" whenever the current is broken its range being limited by a "back stop." This circuit is called the "relay circuit."

Relay-circuit.

2nd. A Bunsen battery is placed in a metallic circuit which passes through the core of a Ruhmkorff, or induction coil, and is complete while the armature of the relay touches the 'contact stud.'

Bunsen battery.

The outer or small wire of the Ruhmkorff coil is carried to the chronograph, one end being attached to the foundation plate, and the other to a style, so that the metallic circuit is only interrupted by the paper, which intervenes between the point of the style and the metal of the barrel.

Ruhmkorff coil.

(30.) The 'relay circuit' being broken by the clock, the relay coils become demagnetized and the armature is drawn away from the 'contact stud' by the spring, thereby breaking the Bunsen circuit and causing the demagnetization of the core of the Ruhmkorff coil. The consequence of the last effect is, that the induced electricity in the outer wire of the coil, which is of considerable tension, owing to the length and fineness of the wire, is discharged through the paper, leaving thereon an indelible mark, always spoken of as a 'dot'. This process is gone through at each beat of the clock, and second 'dots' are recorded on the paper only omitting the first of each minute.

A signal by clock traced.

(31.) An exactly similar arrangement is provided for the 'observatory style,' the 'relay circuit' in this case being broken by the observer at pleasure by means of a key or tappet which he holds in his hand. It should be noted that all signals are made by break of circuit, a method undoubtedly superior as regards instantaniety to the opposite plan of signals by making circuit.

Similar arrangement for observer.

(32.) There must of course be an interval of time between the generation of the singal by the clock, or observer and the record thereof on the paper, and this 'retardation' of the signal has been the subject of considerable discussion. The demagnetization of a coil on interruption of current may be considered instantaneous, for successive changes of magnetization and demagnetization have been obtained at the rate of 14,000 a second (see "Electric Telegraph, Lardner and Bright" page 26). The act in which appreciable 'retardation' creeps in, if at all, is in the withdrawal of the relay armature from the 'contact stud' by the spring, for until the separation is complete the signal cannot pass. The tension of this spring should therefore be as great as possible, compatible with certainty that the attraction of the coils when remagnetized will be sufficient to overcome it, failing which the armature will be held back and the circuit permanently interrupted. A spring which loses its tension very rapidly on being relaxed is the best adapted for the purpose, because the attraction on the armature varies inversely as the square of its distance from the magnet. For the same reason the 'back stop' should also be adjusted to allow as small arrange as convenient.

"Retardation."

Where it occurs.

Precautions.

(33.) The chronograph affords the means of measuring this 'retardation' as follows: If the 'relay circuit' of one style is passed through the other style, so as to be complete while it (the latter) is in contact with the metal of the barrel, then by breaking this contact, a spark is passed through the first style. The first style is placed on a strip of paper and the second on the bare barrel, close alongside, (the metal being scrupulously clean) lines are drawn with thick ink across the paper and metal parallel to the axis of the barrel, and the chronograph is set in motion. The ink lines are quite sufficient to break the metallic contact and record 'dots' on the paper, and the distances of these 'dots' from the lines causing them being compared with the actual distance of the styles apart, afford an absolute measure of the 'retardation'.

Means of measuring 'retardation.'

This experiment has been tried sufficiently to show, that with good current force allowing of strong spring tension, the 'retardation' is barely appreciable, but that it is easy to make it very sensible by decreasing the current force, and necessitating a weak spring.

Provided that the currents used are at all fit for working with, the effect of 'retardation' need cause no anxiety whatever; because, besides the minuteness of the quantity, it must be nearly constant, and so long as it is constant its magnitude is of no importance.

Results of such measurement.

(34.) The paper is prepared by dipping, first in a solution of ferro-cyanide of potassium and then in one of chloride of calcium, the latter being intended to keep the paper properly damp, but it is always sadly dependent on the state of the atmosphere. While working in this dry climate in February I was driven to despair by the difficulty of keeping my paper damp enough, and

Preparation of paper.

a week afterwards in Madras, I was forced to have a lamp always burning below the barrel, because the paper was too damp for use unless it felt quite warm to the hand.

We found chloride of calcium a very difficult article to procure, and I believe we bought up nearly every pound of it to be had in India, in December last.

Batteries 'relay circuit.'

(35.) We have always used Menotti batteries for the 'relay circuit,' as the most convenient from their simplicity and constancy, and because they are universally used by the Telegraph Department in this country. This part of the apparatus gives no trouble, as soon as one has gained very slight experience in adjusting the relays.

Objection to Bunsen batteries &c.

I wish I could say as much of the Bunsen batteries, which on the contrary are very troublesome and require constant care and attention. When all goes well, that is when the Bunsen batteries are working properly, and the paper is in exactly the right state of dampness, the record is all that can be desired, the electric spark leaving beautiful black 'dots' but the slightest fault any where mars the record terribly, and increases in proportion the labour of reading it afterwards. The Bunsen batteries are also objectionable, because of the nature of their ingredients, *viz:*, Sulphuric and Nitric acids, which are very expensive, not always easy to procure, and very troublesome to carry about. For all reasons the substitution of something else for this part of the apparatus, would be a very great advantage.

Preliminary practice.

(37.) I shall now pass on to the actual field operations. In November last we began work with the instruments close alongside of each other, and took a number of observations for practice.

On Base-line.

We then took up positions at the two ends of the Base-line, to connect which a flying telegraph line had been erected, and went through further practice, exchanging stations in the middle. These observations when reduced should afford values of the difference of longitude of the two ends of the Base, and of our relative personal equation, at that time.

Madras and Mangalore.

At the beginning of March we attacked the Madras-Mangalore Arc, Captain Herschel remaining here, while I proceeded first to Madras and afterwards to Mangalore.

Station at Madras.

(38.) The station at Madras was about 65 feet due north of the meridional circle of the Madras Observatory, which Major Branfill connected with our principal triangulation in 1865.

Station at Mangalore.

The longitude station at Mangalore was 63 feet due south of the trigonometrical point.

Telegraph connections.

At Madras advantage was taken of the permanent wire connecting the Observatory with the telegraph office, and at Mangalore a temporary line of about ¾ mile in length was erected between the telegraph office and our station.

At Bangalore, Captain Herschel's station, the S.W. End of the Base, was also connected with the telegraph office.

System of observation.

(39.) Owing to the difficulty of obtaining the use of the lines except for short periods, we were obliged to adopt the system of comparing clocks at certain intervals. Captain Herschel had obtained the concession of the line for four periods of 15 minutes each, during each night, and

Nightly programme.

he adopted the following programme. At hours 8-30 to 8-45; 10-30 to 10-45; 12-30 to 12-45; and 2-30 to 2-45, Madras M.T., the line was claimed for clock comparisons.

The intervals were appropriated to observation of transits, collimation &c., thus:

At Madras 8-50 to 9-10, Transits; 9-10 to 9-55, Collimation and Level; 9-55 to 10-15, Transits; the same order being repeated between each pair of Clock Comparisons.

Exactly the same division of time was observed at Bangalore, only retarded by the difference of longitude, with a view to the same stars being observed at both stations.

Choice of stars.

Acting on this principle, any star is as good as any other for mere determination of difference of longitude, and stars were therefore selected following each other as rapidly as convenient for observation, care only being taken, to observe every Nautical Almanac Star available for the determination of Clock rates. We were thus able to get 6 to 10 stars in each interval of 20 minutes, giving in a full night's work about 45 or 50 stars observed at both stations, and therefore as many individual measures of difference of longitude.

Position of Telescopes.

The Transit telescopes were not reversed on their pivots throughout the observations at Madras, Bangalore and Mangalore, and the position of No. 1 at Madras and Mangalore were the same.

There are advantages in preserving one position, but on the whole I think reversal in the middle of observations at each station would be judicious.

Clock comparisons.

(40.) The method of comparing clocks, which we finally adopted, was as simple as possible. Observer at E (East Station) took the initiative, and at the agreed time gave the ordinary call signal to the telegraph office, continuing it until put in connection with W (West Station). E then placed his clock in circuit with line wire and battery, so as to transmit second signals to W, who received them on his chronograph paper through the 'observatory style,' alongside of those made by his own clock. E continued these until an agreed instant, or until stopped by W breaking his connection with earth, and in either case he immediately prepared to receive similar signals from W. One minute was considered the minimum for a set of signals, and the interchange of two such sets composed one "complete comparison," from which a mean difference of clocks can be deduced with the effect of the transmission delay of the signals eliminated. If no hitch occurred a 'complete comparison' only occupied from 3 to 5 minutes and left 10 minutes at our disposal, we used then to repeat the process reversing the direction of current.

Reversal of current direction.

The first set of signals were always transmitted with zinc to earth at the transmitting station, and this was called "forward current:" for the second set, copper was put to earth by the transmitter, and the current was called "backward." The idea was that a difference of transmission velocity due to current direction might possibly be found, besides which in case of the existence of earth currents (a very common case on the Bangalore-Madras line) they might interfere more with signals given with one direction of current than with the contrary, and therefore the systematic use of both gave the best chance of success. From two 'complete comparisons' the following can be deduced, *viz*:, two mean clock differences, from each of which the effect of transmission delay ($= r$) is eliminated, hence the relative clock rate during the interval becomes known, and lastly, by applying this rate four values of r can be found, *viz*:

Determination of transmission delay.

r	from	E	to W with	'forward current'
r_1	,,	W	to E ,,	do.
r_2	,,	E	to W ,,	'backward current'
r_3	,,	W	to E ,,	do.

If r, r_1, &c. can be accurately determined any signal may be utilised for determining clock difference, if only the current direction be known, otherwise no incomplete comparison can be used without introducing an error equal to r.

System of recording simultaneously on both chronographs.

(41.) For two nights on each section we obtained the use of the line wire for two hours at a time, with a view to trying the system of simultaneous record of transits on both chronographs, a system much superior to that depending on clock comparisons only. Between Madras and Bangalore clouds prevented our taking advantage of this concession, but on the Bangalore-Mangalore section we were more furtunate, and got a good many observations, though not nearly so many as could be desired, owing chiefly to my Bunsen batteries at Mangalore breaking down at a critical time.

On this system we began by a clock comparison as usual, then both of us observed transits, each recording simultaneously on both chronographs, and again compared clocks. Both before and after we each took transits for local clock rate.

Return to Bangalore.

(44.) I returned to Bangalore from Mangalore on the 10th May and we then undertook a set of observations to determine our relative personal equation.

Observations for "Personal Equation."

The instruments were put up alongside of each other, and on four nights we observed a set of stars changing telescopes in the middle of the set each night, and alternating the order so as to eliminate the effect of change of stars' places.

These observations were recorded with a common clock on separate chronographs.

On a fifth night we took divided transits, changing places at the same telescope in the middle of each, and changing the order for alternate stars. We did this with both instruments.

"Style Equation."

(45.) Owing to the two styles following one another on the barrel, the events recorded by the leading style will appear to have taken place later, with reference to the other, than they really did. The correction required to reduce the 'observatory style' to the 'clock style' is called the "style equation" and is generally nearly exactly one second.

Original method of its determination.

Our original system of determining the 'style equation' was by putting the clock in connection with both styles, so that they recorded the same signals on the revolving barrel. If constant strenth of currents could be insured for each relay, the 'style equation' by this method would

contain the effects of 'retardation' of both relays, and therefore in applying it to the observations these effects would be completely eliminated, but practically it is impossible to maintain such constancy of current, particularly when taking the 'style equation' in conjunction with clock comparisons, for then the clock not only makes the double set of marks on the local barrel, but is also in connection with line, and marking on the far barrel.

Objections.

I now think the system of applying the absolute distance, measured by passing a spark through each style on the barrel at rest, is the least likely to introduce error, the effects of 'retardation' being guarded against by the precautions noted in para. 32.

Method preferred.

(46.) With a view to maintaining constancy of current for each relay throughout the operation of comparing clocks and taking the corresponding run for 'style equation', we began working with a somewhat complicated arrangement of batteries, the rationale of which would be troublesome to explain intelligibly on paper. Its chief feature was, that the power was divided into two halves, one placed at each station—that is to say, if 10 cells were required to give a working current on the line, we divided them into 5 at each end, of course taking care that the opposite poles were put to earth. It took us a great deal of trouble to bring this system into working order when we were only separated by the short wire along the Base line, and when we tried it again between Madras and Bangalore, over 200 miles apart, it was, as might be expected, much more troublesome. I believe the difficulty was due to want of perfect insulation on the line, allowing the current to escape to earth, a condition which must obtain in all land wires to a greater or less degree.

Original arrangement of batteries.

Its difficulties.

If the insulation were perfect, the current force on the whole line from 5 cells at each end would be exactly the same as from 10 cells at one end, and if the line were cut at any point (contact with earth of course not being allowed) all current would instantly cease.

Causes of failure.

With a battery only at one end, breaking the circuit at that end must of course cut off all current. But with two batteries acting in concert, when the current of one is cut off that of the other will not cease entirely, because the faults of the whole line will remain open for its escape, and there will be residual current of greater or less force according to the position and resistance of the faults. This was what we found, and the residual current was strong enough to prevent the break circuit signals from the far station being perceived. The system worked well at times, but invariably either became very uncertain in its action or broke down altogether under the influence of dew, which was remarkably heavy at Madras. After struggling to maintain it for some days, we threw it over by mutual consent in favor of the simpler plan of a battery at the sending station only, and from that time we had no further trouble to speak of.

Abandonment.

(47.) I think I may say with confidence, that no difficulty will henceforth be experienced in carrying out such operations, between two stations connected by a fairly well insulated wire of any moderate length, say 500 or 600 miles, and I see no reason to doubt the practicability of using much greater lengths of such line in favorable weather. During experimental work between Madras and Bangalore, we obtained working currents on at least one occasion with only one Menotti cell in use.

Opinion as to future similar operation.

(48.) I shall now offer some remarks on the reduction of the observations. The first thing to be done is of course the transcription of the chronograph sheets, and this is most laborious and trying work, involving several distinct operations. 1*st*. The sheet is examined, and the transits marked out so as to be easily followed. 2*nd*. The 'style equation' has to be applied, which I have always done as follows:—The best mean value of the equation that can be got from the recorded values, is taken up with a pair of compasses and pricked off on the paper several times over, for reference and recovery in case of need. Then putting one point of the compasses in the centre of a transit 'dot' with the other a prick is made in the line of the clock marks, and therefore exactly in the position the 'dot' would have held had the difference of styles been non-existent. 3*rd*. The position of the pricks so made, is read off by a small glass scale on which lines are drawn dividing a second space into 10 equal parts. This being applied to any second containing a prick, so that the outer lines of the scale intersect the second 'dots' the prick is read off to $\frac{1}{100}s$, and by estimation to $\frac{1}{10}s$. The lines of the scale converge, so that it can be adapted to second spaces of different lengths.

The reduction.

Transcription of chronograph sheets.

Application of 'style equation.'

Reading off.

(49.) When the chronograph rate is very bad, and irregular, it may be necessary to apply the equation in this way to avoid sensible errors; but if the rate is fairly steady, as it is in the vast majority of cases, the application of the equation to the mean of observations is all that can be required. The process, has hitherto always been gone through as it does not take long, is more rigorous, and makes the record easier to read, but its advantage is certainly open to question, as the minute errors intended to be avoided are of such a kind as to be certain to cancel each other in the long run if allowed to enter, and moreover similar errors may be introduced in the process of applying the equation.

Remarks on the process.

The rate and ease of reading off is very dependent on the clearness of the record sheet, and the rate of the chronograph. Under favorable conditions, I have pricked off and read 33 transits, aggregating 635 wires, in 2 hours, which gives an average of 5·3 'dots' per minute.

(50.) Every wire read is reduced to the centre wire, for which purpose the wire intervals were computed for every star observed; the Equatorial intervals having been in the first place determined by numerous transits of stars of small N.P.D. The case of missed wires is so common, that this method is very much simpler than that of reducing to the mean of wires.

Reduction of transits to centre wire.

(51.) All Nautical Almanac stars observed are used to determine the clock rate and azimuthal deviation at each station, each night, and this I think has been the weakest part of our work, and the part most open to improvement in future similar operations, first by the introduction of distant referring marks or better fixed collimators, and second, by more attention to the stars used for the purpose.

Stars observed for clock rate and azimuthal deviation.

But no possible error in these determinations can appreciably affect the results of our past work, because absolute rate is only required for the reduction of one clock to the other, for the interval due to difference of longitude, or during about 11 minutes.

Absolute clock rate of little consequence on that arc.

The importance of this point increases in direct proportion to length of the arc of longitude under measurement.

(52.) Both determinations of local clock rates are combined with the relative clock rate given by the clock comparisons, to deduce an absolute rate for one clock. In doing this the relative rate by the comparisons is considered as correct, being far more trustworthy than that given by a combination of the two computed absolute rates. The two latter are then assigned weights, (somewhat arbitrarily) according to their agreement each day with the mean of all days, on the grounds that the clock comparisons, as well as the daily clock errors, show that the general clock rates were very steady.

Combination of clock rates.

The following simple combination then gives the absolute rate adopted, say for the west clock, $= \frac{n r_W + m (R - r_E)}{n + m}$, where r_E, r_W are the computed absolute rates, with weights m, n, and R is the relative rate by clock comparisons.

This is the course which has been followed in the reduction of the Bangalore-Mangalore observations, but it may require modification on other occasions.

(53.) The relative clock rate is found to vary slowly during each night's work, and its value then is different from the value during 24 hours. These differences for stations Bangalore and Mangalore are shown in table IV.

Relative clock rate varies.

It would be interesting to compare these changes of rate with readings of the Barometer and Thermometer taken during the observations, and it is a pity that it never occurred to us to use those instruments.

(54.) I shall now proceed to give as much information as possible as to the results obtained.

Results.

The results of our observations for relative personal equation are given in table V and give a mean value of 0ˢ·036, Captain Herschel's time of observation being so much later than mine. Another value of equation will I hope be arrived at when the observations on the Base line are reduced, and it will certainly be more satisfactory to have a value both before and after the principal operations, but we had both done so much preliminary practice before commencing the final work, that we must have entered on the latter with strongly acquired habits of observation, and no after change in our equation need I think be apprehended.

Personal equation.

(55.) The resulting values of difference of Longitude between Bangalore-Mangalore are given in table VI and these may be considered as nearly final, though possibly open to slight corrections, which may be arrived at by treatment of the results themselves.

Difference of longitude Bangalore-Mangalore.

(56.) Let us examine how such a discrepancy can arise, first supposing it to be certain that there was no mistake in the identity of the star observed at each station. The clock comparisons show the relative rate to progress so steadily, that it must be considered as beyond suspicion, that is to say, these discordances cannot be reasonably referred to irregularities in either clock.

Discordance of results examined.

They cannot arise from erroneous clock rate.

The mean *p.e.* of a transit, as given by 10 cases chosen at random, is $\pm$ ˢ·0068 and $\pm$ ˢ·007 for Telescopes Nos. 1 and 2 respectively, therefore the combination of the two will only account for a probable difference of ˢ·010, and an extreme difference of say ˢ·025. There only remain the instrumental corrections to be considered, viz: the corrections for Azimuthal deviation, collimation, and dislevelment for each instrument. Of these, the first must be absolved, because any discrepancy arising from it, could not fail to be traced at once, by comparing the results of North and South zenith stars, and if such were traced it would be easy and legitimate to correct it. We must therefore turn to the collimation and level corrections and here we find ourselves face to face with the fact noted in para. 17, viz: that from the collimation and level readings of Telescope No. 2, no certainty can be placed on any value assigned to these corrections, and an equal uncertainty must attend all observations taken with that instrument.

Nor from observation errors of transits.

Or errors of Azimuth.

There remain only errors of collimation and level.

Uncertainty as to these errors of Telescope No. 2.

(57.) The errors thus caused may be of two kinds—1st. they may be very uncertain, and therefore tend to cancel each other; or 2nd. they may be regular, thus introducing a constant error in the results. If the first, their existence need cause no anxiety as regards the result of a considerable series of observations; if the second, we may hope by a course of observations adapted to the purpose to arrive at conclusions, which will enable us to correct the results now obtained.

Resulting errors may be of two kinds.

So far as can be judged by comparing the resulting differences of longitude, given by the same star on different nights, these errors appear to be of the first kind. This is corroborated by the observations for personal equation, when the results of both instruments are combined, and treated so as to give a value of personal equation, and also of the difference of longitude between the two positions.

Most probably irregular.

This is corroborated by observations for personal equation.

The value of the equation so obtained was very good (see table V), but the deduced values of difference of longitude on different nights were, $-0^{s}\cdot025$, $-0^{s}\cdot004$, $+0^{s}\cdot072$ $-0^{s}\cdot102$; mean $= -0^{s}\cdot015$. The actual difference of position was 50 feet $= +0^{s}\cdot033$, which gives an error of $-0^{s}\cdot048$ to the mean deduced value, but this result evidently cannot be trusted as an indication of any constant error, because the deduced value, $-0^{s}\cdot015$, has a probability of error $= \pm 0^{s}\cdot036$, actually more than double its own magnitude.

I have referred these discrepancies to Telescope No. 2 only, because the collimation readings of the other show no signs of similar faults, it would, however, be unsafe to conclude that that instrument is perfectly free from them, and indeed it is nearly certain that every instrument must be similarly affected in some degree, if the cause be as suspected irregularity of flexure.

Telescope No. 1 probably not wholly free from such defects.

(58.) From all the clock comparisons taken between Banglore and Manglore, values of the transmission time of a signal, viz: $r\ r_1\ r_2\ r_3$ (see para. 40) have been deduced (by Captain Herschel before leaving) and are given in his report. The results are very interesting and possess features which seem to call for remark and in some respects for explanation if possible. The only determination of this velocity by other observers to which I have access, are those given in the Monthly Notices of the Royal Astronomical Society as follows: (See February 1872 p. 179 and February 1873 p. 233).

Determination of transmission velocity of a signal.

by other observers.

1*st*. By special experiments in America between Cambridge and San Francisco—Mean transmission time through 7,200 miles of wire, including 13 relays $= 0^{s}\cdot827$, whence velocity $= 8{,}706$ miles per second.

American.

2*nd*. During the Electro-longitude operations in Switzerland already alluded to (para. 55) the velocities of 7,300, 7,840 and 9,000 miles per second were arrived at.

Swiss.

3*rd*. Your own approximate observations with Major St. John R.E. between London and Teheran gave the velocity through 3,870 miles with 5 relays at more than 7,740 miles per second.

London and Teheran.

Of these the American determination appears to be the most valuable because resulting from special experiments, and it seems reasonable to assume that it was obtained under various conditions of current direction, in which case it should be comparable with our mean value of 15,312 miles per second, affording a difference of no less than 6,606 miles per second to be accounted for.

American value preferred.

And compared with ours.

As mentioned above, the American signals passed through 13 relays, and were necessarily retarded by each. Our results on the contrary are only affected by *difference of relay retardation*, because they are obtained from the comparison of two signals of which each passes through one relay, and one through the line wire in addition.

Attempted explanation of discrepancy.

(59.) The discrepancy between our values with opposite current direction is very great—'forward' current giving a velocity of 9,800 miles per second and 'backward' 35,000 miles. Some part of this may perhaps be due to relay action, as I shall try to explain.

Difference of our results due to direction of current.

Partly explained.

When the direction of the line current was reversed that of the local clock relay was left as before (which was rather an oversight) and consequently in taking a comparison 'forward,' both sets of signals (distant and local) passed through the relay coils in the same direction, whereas with 'backward' current the directions through the two relays were opposite, and it is posible that this difference may affect the relay retardation, and as stated above relative relay retardation enters into every comparison. If this effect does exist to an appreciable degree, it will not be difficult to detect it by experiments which I propose to try as soon as convenient.

Considerable discrepancies, however, in such results as those under investigation, will not be wondered at when the minuteness of the quantities, (owing to the short length of wire used) the comparatively large errors which may possibly be introduced in the process of dealing with them, (reading off the chronograph sheets for instance) combined with the small number of individual observations, are kept in mind.

Uncertainties of such determination.

But all these considerations combined, seem to me to be insufficient to explain away the difference of velocity, according to current direction, at which we have arrived.

(64.) The general arrangements with the Telegraph Department were of course made by Captain Herschel, but both at Madras and Mangalore, particularly the former, many details were left to my care and I beg here to record my gratitude for the attention and courtesy shown to me on all occasions by the officers of that department with whom I was brought in contact, particularly J. Burke Esq. Officiating Superintendent, Madras Division and W. P. Johnston Esq. Assistant Superintendent, in charge Head Office. My best thanks are also due to Mr. Pogson, Government Astronomer of Madras, who took a pleasure in facilitating my operations in every possible way.

Personal acknowledgements.

My Assistant, Mr. Bond, superintended all building operations, preceding me to Madras and Mangalore for that purpose, and also executed a considerable quantity of computations (for wire intervals &c.) in the field. I have every reason to be satisfied with him, and his promotion to a higher grade on 1st July last was well deserved.

Since Captain Herschel's departure his Assistant, Mr. Belcham, has been at my disposal, and I have found him an excellent computer.

Lieutenant Harman R.E., who arrived here, from Head Quarters at Dehra, on 20th August, has at your desire given me his aid in office, and I owe him thanks for the zealous manner in which he has attacked the work.

(65.) In conclusion I would express my regret, that Captain Herschel should have been obliged to leave in an unfinished state, the operations of which he has had chief charge from the beginning, and I feel bound to guard against the possibility of any of the credit, which is due to him, being transferred to me by the accident of his departure at such a time, leaving the completion of the work, and to a great extent the reporting on it, in my hands. The conduct of the operations was his throughout, and whatever credit may be considered due to the results belongs properly to him. For my own part, I am very sorry that his departure should have brought to a close our association in these operations after so short a campaign.

Conclusion.

Table IV.

Longitude operations. Arc Bangalore-Mangalore. Abstract of relative Clock rates deduced from Clock comparisons.

Date	Clock difference by comparisons	Mean hour of comparison	Deduced relative clock rate per hour	For each night: Mean clock difference	For each night: Mean hour	Deduced *daily* relative rate per hour	Remarks
	m s	*h*	*s*	*m s*	*h*	*s*	
April 26th	12 25·215	14·835	·666	12 25·869	15·817	·643	This Table is expressed in sidereal time, which was about 2½ hours in advance of Mean time.
	12 26·523	16·798					
„ 27th	12 38·065	10·837	·659				
	12 39·386	12·841	·659	12 39·388	12·844	·623	
	12 40·712	14·854					
„ 28th	12 53·097	10·909	·660	12 53·786	11·953		
	12 54·475	12·997					
„ 29th	13 8·068	10·973	·641			·622	
	13 9·352	12·977	·634				
	13 10·616	14·972	·621	13 9·980	13·984		
	13 11·885	17·015					
„ 30th	13 22·967	10·985	·669			·623	
	13 24·308	12·988	·661	13 24·310	12·999		
	13 25·654	15·024					
May 1st	13 37·688	11·065	·635			·609	
	13 38·974	13·091	·630	13 38·970	13·090		
	13 40·247	15·113				·608	
„ 2nd	13 54·469	14·663	·649	13 55·088	15·617		
	13 55·706	16·570				·623	
„ 3rd	14 9·500	14·817	·658	14 10·068	15·679		
	14 10·635	16·541					

The published notices of the Meteorological Observatory at Bangalore gave the following means for week, from 27th April to 3rd May. Thermometer daily means. Dry 81°·2, Wet 61°·7, Max. 95°·7, Min. 70°·8 Barometer and Humidity both steady throughout.

No such data are available regarding Mangalore, but the daily range of temperature there must have been much smaller than the above, and was probably included between 87° and 78°. At Bangalore a harsh dry west wind prevailed, generally lulling during the latter part of the night. At Mangalore a fresh sea breeze blew all day, dying away at night.

The clocks at both stations were about equally protected.

Table V.

Results of observations at Bangalore May 1873, for determination of relative personal Equation of Captains Herschel and Campbell.

Method of determination	No. of observed values	Mean value $H-C$ / E	Mean value $p.e.$	Combn. weight W	$E \times W$
		s			
By sharing transits, Telescope No. 1	20	+ ·043	± ·0046	47100	+2025·3
do. do. do. 2	21	+ ·026	± ·0043	54300	+1411·8
By reduced transits on four nights, Telescope No. 1	48	+ ·068	± ·0063	24800	+1686·4
do. do do. do. 2	61	+ ·014	± ·0064	25000	+ 350·0
By reduced transits of both instruments combined with their ΔL.	113	+ ·038	± ·0066	22700	+ 862·6
Sums ...	263	...	...	173900	+6336·1

Adopted value of Equation, or $(H-C) = +\frac{6336\cdot1}{173900} = +^{s}\cdot036$ $(\pm\cdot0024)$ which means, that the time of an observed transit by Captain Campbell must be corrected by $+^{s}\cdot036$ to make it comparable with the same observation by Captain Herschel.

Table VI.

Longitude operations. Arc Bangalore-Mangalore. Abstract of Results.

INDIVIDUAL VALUES ON EACH DAY

Ap. 26th	Ap. 27th	Ap. 28th	Ap. 29th	Ap. 30th	May 1st	May 2nd	May 3rd	May 2nd *	May 3rd *	
10′	10′	10′	10′	10′	10′	10′	10′	10′	10′	
s	s	s	s	s	s	s	s	s	s	
56·71	56·71	56·85	56·64	56·74	56·87	56·93	56·85	56·74	56·92	* By transits observed at Bangalore, and recorded on both chronographs.
·73	·78	·81	·76	·75	·89	·72	·85	·78	·85	
·62	·76	·73	·81	·68	·79	·74	·80	·84	·70	
·74	·76	·75	·78	·66	·85	·72	·78	·75	·90	
·70	·74	·79	·70	·79	·76	·79	·82	·73	·81	
·65	·69	·71	·65	·64	·78	·71	·76	·59	·83	
	·69	·71	·61	·72	·79	·65	·63	·74	·94	
	·59	·73	·76	·67	·86	·57	·81	·63	·88	
	·60	·75	·79	·68	·91	·71	·71	·65	·88	
	·62	·66	·73	·67	·83	·61	·72	·75		
	·61	·68	·78	·62	·76	·63	·83	·67		
	·59	·68	·72	·61	·77	·73	·79			
	·73	·66	·80	·73	·79		·79			
	·72	·67	·62	·63	·87		·83	56·719	56·852	Means
	·74		·69	·67	·60		·79			Correction for transmission time, W. to E. deduced from the observations themselves.
	·75		·71	·82						
	·73		·59	·80						
	·68		·75	·58						
	·66		·72	·65						
	·68		·65	·81						
	·69		·65	·73				−·028	−·033	
	·73		·56	·78						
	·68			·70						
	·62									
	·65							Corrected		
	·68									
56·692	56·688	56·727	56·703	56·701	56·808	56·709	56·784	56·691	56·819	Means
±·0130	±·0075	±·0105	±·0105	±·0096	±·0132	±·0182	±·0104	±·0148	±·0162	*p. e.*

General Mean (using combination weights) $= 10^{m}\ 56^{s}\cdot723 \pm \cdot0036$

General Mean after correction for personal equation $= 10^{m}\ 56^{s}\cdot759 + \cdot0013$

N.B. Correction for personal equation $= +^{s}0\cdot036 \pm {}^{s}\cdot0024$, to observed time of observer at Mangalore, or West Station.

Extract from the Narrative Report—dated 9th October 1873—of Lieutenant A. W. BAIRD, R.E., Assistant Superintendent 1st Grade, in charge Bombay Tidal and Leveling Party.

History of the Party.

The Bombay Leveling Party was formed in October 1869, and I was appointed in charge of it D.O. No. 55 of 1869 dated 27th September 1869, to be employed in connecting together and reducing to the common datum of mean sea level, the various lines of levels which had been executed in the Presidency in the course of Irrigation, Railway, or other Public works, and it was contemplated to commence operations to determine whether any change of the relative level of land and sea in the Runn of Cutch was going on.

Certain changes rendered it necessary for you to order the services of the Party to be placed under the late Colonel Nasmyth, R.E., for employment in the Guzerat Party, *vide* D.O. dated 1st November 1869. In consequence of the reduction of expenditure in the Survey Department, ordered by the Government of India, the operations of the Bombay Leveling Party were ordered to be suspended, and the party to be broken up, by D.O. dated 31st March 1870.

By letter from the Officiating Superintendent G. T. Survey No. $\frac{1}{1016}$ dated 16th August 1872, I was ordered to consider myself in charge of the Tidal and Spirit Leveling operations, in the Bombay Presidency, and as a preliminary arrangement to obtain copies of all the correspondence, in connection with the subject, from Major Haig, R.E., and Captain Trotter, R.E.

A few Khalásis and one Native Sub-Surveyor were entertained in October 1872, for the nucleus of the Party, which was then formed as the Bombay Tidal and Leveling Party. The services of the Native Establishment of No. 4 Extra Party, were placed at my disposal for employment with the Bombay Tidal and Leveling Party on the completion of the Pendulum operations in Bombay. This took effect on the 1st April 1873. The Native Establishment of No. 3 Extra Party was also transferred to the Bombay Presidency, to be employed in the operations, by D. O. dated 4th August 1873. Mr. F. Bell, Surveyor 3rd Grade was transferred to the Party, by Departmental Order dated 11th August 1873.

Reconnoisance of the Gulf of Cutch to fix three Tidal Stations.

In November 1872 you ordered me to proceed on a reconnoisance of the Gulf of Cutch, for the selection of sites for the Tidal Observatories, and sent me certain instructions for guidance on the subject: "One being required as far into the Runn as possible, to which the tide has free access &c." "Another near Beyt Island and a third as nearly as possible equidistant from the two former." The stations were to be all on the south side of the Gulf if practicable; if not, the north side of the Gulf to be examined. Failing to find any of these sites, the south coast of Kattywar was to be examined.

In compliance with your verbal orders given prior to the letter above mentioned, I left Bombay on the 13th November 1872, to carry out the reconnoisance, and proceeded *viâ* Rajkote to Jaoria Bunder close to the head of the Gulf of Cutch; and then I received your letter with instructions above referred to. I hired a small country boat without delay, and commenced the examination of the foreshores of the Gulf. I informed you of some of the difficulties I had to contend with in procuring a boat &c. but I completed the duty sooner than I anticipated, and returned to Bombay at once, to follow up your further instructions. The report of my reconnoisance of the Gulf, brought to your notice the various places I visited, and examined, and those I finally selected.

Results of Reconnoisance.

The results may be briefly stated as follows:—Hunstul about 18 miles from Jaoria at the head of the Gulf, Nowanar on the Cutch coast about 15 miles from Moondra, and Okha point, opposite the island of Beyt, were considered the only points suitable. Hunstul point had 72 feet of water at low water, within 100 feet of the shore, Nowanar 19 feet and Okha point 23 feet. Hunstul is about 16 miles from the nearest village where drinking water can be procured, Nowanar is 9 or 10 miles from drinking water, and Okha point has Beyt within 1 mile, but a boat would be required for communication with it. With the exception of Nowanar being on the Cutch coast, the actual positions of the selected sites almost exactly coincided with those required, and you were pleased to convey your approval of the way the reconnoisance had been executed.

Return to Bombay to make preparations for the trial of Instruments &c.

Having selected the sites for the Tidal observatories I proceeded to Bombay, to carry on the alterations to the old machines, in order to utilize the scales of wheels for different ranges of the tides &c., to procure pipes, cylinders, observatories, &c. and make all the arrangements, for taking up every thing requisite for carrying on the Tidal observations on the Gulf.

I arrived in Bombay on the 9th January 1873, and after a few days I arranged with Major Merewether, R.E., to be allowed to carry out my work at the Harbour-defence workshops. This was the most convenient place for the purpose, as I was enabled to have every thing done on the spot without delay, and under my own superintendence.

General site of the observatories settled.

The first thing to be decided on, was to arrange how the observatories were to be fixed, whether on dry land close to high water, and having a pipe connection with the sea, or actually in the sea on Piles. I submitted various proposals after having made enquiries regarding cast and wrought iron piles &c., for your consideration ; finally you decided on adopting the positions for the Tide Guages in the vicinity of the high water line.

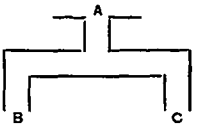
General details of the arrangements to be followed.

A water tight iron cylinder for the float to work up and down in, with a pipe of sufficient diameter—*viz*; 2 inches—to connect with deep sea, has to be sunk to a depth of 3 or 4 feet below the level of the sea, at Low Spring Tides ; and the only feasible way of carrying this out—considering the nature of the ground—secured to be by sinking a brick well of small diameter, to receive the cylinder; arrangements have been made accordingly. The cylinder having been placed in position, a two inch wrought iron gas pipe will be connected with the bottom of the cylinder by a small bend, this pipe will then be brought up vertically to a height corresponding with 1 or 2 feet below the lowest high water. The bank will be cut away as quickly as possible to this depth, and the pipe taken straight out, until it reaches the sloping surface of the shore, and this it is hoped, will be done by working as many men as possible, in clearing away the sand when the tide is very low. The rigid iron pipe is then to be carried down along the slope to reach low water springs. Here a brass connecting arrangement will be fitted, to which a flexible gutta percha pipe of 2 inches diameter with a rose at the end, will be attached, and carried out about 120 feet to the deep water. The extreme end of this pipe with the rose will be supported 3 feet above the ground under water, by a small buoy fixed to an anchor by a chain ; and this buoy again will have a chain attatched to it, thus connecting the whole to a mark buoy on the surface of the water, which will rise and fall, with the tide. It is hoped by this means to secure the pipe from being filled up with silt, and choking. The size of the pipe, and the number of holes of the rose, and their size, have been calculated, (and a sufficient margin left in case of small quantities of silt getting deposited) so that the rise and fall of the water in the cylinder may correspond with that of the sea. Two of "Bull's Dredgers" have been bought to use in sinking the wells, and the wooden framework and bricks have also been purchased for this purpose.

General description of the apparatus &c.

The cylinders for the project have been made up in sections of 4 feet 2 inches in length, with an interval diameter of 22 inches. A sheet of wrought iron being bent to the size required, and rivetted to form a cylinder, a cast iron flange was fitted on to each end, and the faces of these carefully turned. The size of the cylinders was decided on so as to utilize the iron sheets most economically, and when finished 4 men could carry one of these sections. The bottom section will have a flat iron plate carefully screwed to one end, to represent the bottom of the well. The holes for the bolts and nuts have been carefully fitted and when *joined*, the whole cylinder will form a water tight well. The two-inch gas pipe was bought in Bombay and had thimbles for connecting the lengths together, but it has since been found, that even with the greatest care, there is a chance of leakage which would be a cause of great anxiety and trouble ; so, small cast iron flanges have been made up to screw on to each end, and this will render the connection water tight, and the pipes will be more easily fixed together. A stop-cock has been carefully fitted on to the top bend for each Observatory, for exhausting the air in the first instance. The brass connecting arrangement here described, has been procured for each place, to connect the rigid and flexible pipes.

The iron pipe is fixed by a flange at **A** ; at **B** the long flexible pipe is screwed on, and at **C** a brass disc is also screwed on. When the flexible pipe has to be examined for cleaning, the disc will be unscrewed at **C**, (under water of course) a short length of spare flexible piping with a rose at its end, fitted on, and taken out to deep water temporarily. The pipe at **B** taken off, and cleaned, the disc being screwed on at **B** temporarily ; then when finished, the long pipe is replaced at **B**, and the disc at **C**. In this way it is hoped there will be no stoppage in the work. The flexible pipe is 2 inches diameter with copper inside, just the same as suction pipe. These pipes are in lengths of 50 or 60 feet, the smaller ones for temporary use only 20 feet : they have couplings and unions for connecting with each other. The rose at the end is a copper cylinder about $2\frac{1}{2}$ inches diameter, with 150 holes of $\frac{3}{10}$ of an inch bored in them, and have screws for fitting on to the end of the flexible pipe.



The buoys are what is termed Nun Buoys, and have been procured on indent from the Dockyard. The smaller ones have an arrangement attached to them for holding up the rose at the end of the pipe, and will be secured to an anchor so as to be always 3 feet from the bottom. The upper end, as I have previously mentioned, will be attached to a chain fixed to the upper buoy, which will float on the surface and mark the position, and also be the means of lifting up the pipe for cleaning. This is a rough sketch of the plan to be adopted, as far as we can, and it is believed that with very small modifications, which may be necessary, and can be determined on the spot, that the arrangement is the most effective, and simple, for the purpose. A cleaning rod, in lengths of about 12 feet, with a brush at the end has also been made up.

The observatories themselves are 12 feet by 9 feet and about 12 feet high in the centre, the roof sloping from the ridge to the sides which are about 8 feet high. They have been made as portable as possible, and are clinker-built, but it was found in Bombay that a tarpaulin was necessary to keep out the rain which is very heavy here during the monsoons. All the other material for the construction of the observatories on the sites selected has been procured, and with the exception of the sheds for the men in charge to live in, very little has to be bought on the spot.

Fifty Bench-mark stones have also been made up, and cut in this manner, ready to be laid down.

The description of the observatories in working order will more properly be reported on when they have been finished and fixed, but what I have said brings to your notice what has already been done. The size of the observatories has been found to be most convenient; when all the instruments are fitted up, perhaps an additional 6 inches in width would be an advantage.

Arrival of the machines.

The self-registering tide gauge No. 7, which had all the latest improvements—such as friction rollers, improved pencil holder, swivel for the float &c.—and one self-registering Aneroid Barometer, were received from England in November 1872, when you were in Bombay. The remaining five Aneroid Barometers, and six self-registering Anemometers together with some differential scales, and other Office requirements, were received about the end of May 1873. Tide Gauges Nos. 2 and 3 had been lying in the Superintending Engineer's stores in Bombay for some time. No. 1 was received from Major Branfill, Madras Party, and also Nos. 5 and 6 from Calcutta, so that with the exception of No. 4 all the Tide Gauges, I believe, are now in my charge.

Alterations of the Instruments &c.

While the cylinders, piping, and Observatories for the Tidal Stations were being made up, the alterations to the self-registering Tide Gauges were commenced. Friction rollers were made up here for Nos. 2 and 3, and those that came out from England were fitted on to Nos. 1, 4 and 5. The pencils for all have also been made similar to No. 7, as also swivels for the floats, and generally they have all been overhauled. I tried various plans for fixing the diagram on the barrel, and finally adopted clips secured to the barrel with screws, and having a small moveable plate to be jammed by two pinching screws, one of which is rivetted to the plate and the other free. This has been found to answer admirably, and it has been fitted to all the Tide Gauges. Zero lines for height, and 12 o'clock lines have also been carefully marked on the barrels, so that by rubbing with a hard pencil on the paper diagram, they are transferred to it. I regret to say that the barrels of all the instruments are not quite circular in cross section nor are they quite straight longitudinally. This is the fault of the maker who probably found the sheet brass too thin to turn on a lathe. Also one of the barrels which came from Calcutta has been seriously indented, and the pencil was bent and rendered useless: the latter has been repaired, but the barrel must be left as it is. Scales of wheels for working the various tides to most advantage, to suit the 5 feet barrel, as sent out by Mr. Adie, have been fitted to all the machines, and in order to do this, various parts of the instruments had to be made entirely new.

The self-registering Aneroids have also had some slight alterations made. These instruments were received from England so rusty in some parts, that it was imperative that I should hand them over to an experienced watchmaker at once. The clock hands, pointers of the aneroids, and the small hooks at the end of the gold threads, had to be cleaned and oiled, and when possible, covered with a coat of protecting lacquer. Also two of the gold threads were imperfect, one being broken altogether. The action of the escapement of the clocks in some of those last received, have given a great deal of trouble. The repairs of these instruments have been executed very well: a longer arm of iron being put on to make up the deficiency of the length of the broken gold thread. It is to be regretted however that out of the 6 instruments, 2 are by no means working properly, and may have to be sent back to England for repair. Zero lines for height have been marked on the barrels.

The Anemometers came out safely from England with the exception of one which has been repaired here, but all the clocks had the main springs in such a rusty state, that it was apparent new springs would have to be got at once, and accordingly arrangements were made for getting out good springs without delay, and they are expected by next Overland Mail, so it is to be hoped the alterations will be finished before we leave for the Gulf of Cutch. After working these instruments as will be afterwards mentioned, some alterations were necessary to keep out the rain water from the working gear; this has been done by fixing on small copper covers like candle extinguishers round the outer shafts, also by fixing a piece of tube to the bottom of the small box on the top, to prevent water getting down the velocity shaft, and an escape hole drilled in the box.

These are the main alterations to all the machines.

The next thing to be noted is the arrangement followed in Bombay to test the working of the machines. On account of the sea receding at low water spring tides too far from the Bunder, it was necessary to adopt some plan, for the water being prevented from leaving the connecting pipe with the cylinder. This was done by causing the 2 inch pipe to end in a small tank, as low down as possible. As the friction at the vertical bends would be the main cause of any retardation to the flow of water, the piping was given several vertical bends in order that the test should be much more severe than the actual conditions of the observations at the tidal station on the gulf of Cutch. Three cylinders were erected side by side, *i. e.* about 9 feet apart, their observatories being close together. The small 2 inch pipe in connection with each ended in a tank to represent low water mark. The basin in which the gauges were erected was unfortunately one in which a great deal of thin mud settled. The 2 inch piping entered each cylinder about 9 inches from the bottom; it was 300 feet long in 2 instances and some thing short of that in the other.

Arrangement followed in Bombay to test the working of the machines.

The connection having been made, it was apparent after a few days that a quantity of air must have collected at the upper vertical bends of the pipes, as the water did not rise and fall properly in the cylinder, stop-cocks were inserted at the highest vertical bend in each system, and these when opened under water allowed the air to escape, and at first it seemed as if all had been extracted and the arrrangement working properly. On the 20th May Nos. 2 and 3 cylinders were working properly, the water inside being measured from the top of the cylinder very carefully with a measuring rod, and compared with the reading of a temporary tide gauge which had a fixed relative height to the cylinder.

Difficulties arise from the air in the connecting pipe.

From 1st to the 25th June, both Nos. 2 and 3 cylinders worked well, but in placing the pipe for No. 1 down in the tank, a bad connection had been made, and there was a leak evidently in the pipe: this drew the water out of the small tank at the first low tide, and so spoiled the working of all three cylinders. The piping for No. 1 was carefully relaid, but it was some time before it was considered satisfactory. No. 2 cylinder after the 25th June did not require to have the stop-cock opened until the end of the experiments. In Nos. 1 and 3 air seemed to collect in small quantities, and it was very difficult to exhaust it, so much so, that I tried all sorts of plans before succeeding. The difficulty was that at high water the sea covered the stop-cock.

Now at the future tidal stations the sea will not have access to the stop-cock, and so if it is opened at high water the pressure of the sea water (which is higher than the stop-cock of course) will drive out the air, and there will be no superincumbent column of water to keep it in.

To get over this difficulty in Bombay I had a small tube about 3 feet long screwed into the stop-cock of No. 1, so that on opening the stop-cock when the sea was well over it the water did not act above the orifice to keep the air in, and it rushed out at once, and the water inside the cylinder quickly assumed the same level as that of the sea outside.

Having set up the tide gauges on trestles and arranged their floats &c., I then had an anemometer put on a shelf in each observatory; taking care to place the whole of the working gear for outside, well clear of the ridge. In putting up these instruments great care has to be taken. The long pipe in which the several rods and pipes work, must be allowed to assume its own position without being forced in any way, otherwise the crown-wheels at the bottom may be thrown completely out of gear. Also, the cups must be fitted on properly not upside down otherwise the spiral will turn the wrong way and tear the paper on the barrel and perhaps seriously injure the instrument.

Anemometer set up.

After several days with various results from the 3 instruments almost side by side, it was thought advisable to put a flat flooring about five feet square outside, immediately above the ridge piece, to prevent eddies underneath the cups and fans. No doubt this had some beneficial effect, but unfortunately in the trial of the instruments, a much more serious cause of error was found out, so that it was impossible to say, how far the arrangement acted to keep away any back draught of air, which it was supposed would occur from the shape of the roofs.

Flooring underneath anemometer.

A self-registering aneroid barometer was also set up in each observatory. A rain gauge was also set up outside.

The levels of the bed-plates and tops of the cylinders were approximately connected for comparisons with the temporary tide gauge, and making allowance for the swell (causing the float of the temporary tide gauge to be unsteady) the water inside and outside being found to correspond in level, a comparison of the position of the pencil on the diagram, to the depth of the water in each cylinder from bed-plate was made.

Levels of bed-plates of the tide gauges connected; comparison of the height of water and 30 inch line on diagram.

During the time the machines had been put up and were being tried, I engaged some natives for the work in the observatories, and taught them what was to be done, and by the time the instruments were put on trial they were fairly well acquainted with their duties; they were all young and inexperienced consequently they have come on small pay, but I have every hope of their doing their work satisfactorily, and meanwhile I have called them Apprentice Sub-Surveyors. I have also had daily report forms printed for transmission to me; 3 sets of these, filled up for the month the instruments were being tried, accompany this report just as they were sent me by the Sub-Surveyors.

Sub-Surveyors taught the work in the observatories.

The results of the trials of the tide gauges may be considered very satisfactory; there were some interruptions, in the continuity of the work; but these I think are most unlikely to happen at the Gulf of Cutch, and with ordinary care the Sub-Surveyors ought not to have any breaks in their work. As regards the rats eating the diagrams, I have tried poisoning them but with no great effect: it is believed that blue stone mixed with the paste will keep them off: ants also may get at the clocks and this will always be a source of anxiety, and these (or the rats climbing up the pendulum) may stop the clock; still chalk lines drawn round the feet of the trestles may prevent the ants passing up, and I have also been advised to put some wood ash all round the feet on the floor. The diagrams, of which a set are submitted, speak for themselves, and you will observe that the jagged lines only occur at the head of the curves, just when the swell has time to act, *viz.* at the turn of the tide, when there is no rise or fall to speak of, for some time, and so the pumping action has time to make itself felt.

General results.

Regarding the aneroid barometers I do not consider them satisfactory instruments. Two are useless, but of the remaining four, I am in hopes of getting three safely up to Cutch, and if so they will give good results. But I thought it advisable to recommend to you that one mercurial barometer, should be placed in each observatory, so that readings might be taken at different times during the day; these would fulfil the double purpose of being a check on the Aneroids, and also in case of the failure of the latter there would be a set of independent barometric readings; this proposition you have sanctioned.

With regard to the working of the anemometer, the results of the trial have given me a very good deal of experience, and I have been enabled to make such alterations, and additions to these instruments which I think will fulfil the purpose for which they are intended; and it is most likely now that 5 of the 6 instruments will give very correct results, and no annoyance with proper care in the future operations.

The rain gauges are simple bottles in a tin case with a tube attached to the top (which is moveable) going into the bottle: also a glass measure: they are by Casella: and there is of course no trouble with them. One thing I may mention, that the rain is very local here, often half an inch in a day more at the workshops with one of the same gauges than at the observatories was registered, the distance between those places being about $\frac{1}{4}$ of a mile.

There is still one thing to be ascertained about the self-registering tide gauges, and that is whether the stop-cock must be opened or not after the air has been thoroughly exhausted, which can be done in a couple of high tides. The results of the working of No. 2 observatory would seem to settle the point: for, the stop-cock there was not opened for nearly 3 months, and yet the action of the water in the cylinder was perfect during that time. But in Nos. 1 and 3 observatories air collected at the top bends. I feel very confident that a leak, perhaps very small, occurred in the connecting pipes there. The gas pipes were screwed together by thimbles and were very difficult to lay, and I think were the cause of the leakage. I have, since the pipes were taken up, got small cast iron flanges fixed on to these gas pipes, and I am now almost sure of an air-tight connection: and the pipes will be much more easily laid. By opening the stop-cocks for a second or two at high water, there will be no chance of air collecting and it does not interfere with the working of the instruments.

On the whole then I think the testing of the instruments show, that now we may expect very good results if they are carefully looked after, and no unforeseen accident causes any interruption.

The bench-mark outside the gate of the Harbour Defence Workshops, marked in Mahratta (270), and close to the post office pillar, was connected by leveling with the bed-plates of the tide gauges in No. 1 and No. 3 observatories, and also with another bench-mark on the 14th step at the end of the Harbour Defence Bunder.

Bench-marks in connection with Town Hall datum connected with the bed-plates by leveling.

From this it was an easy matter to lay down on the diagrams of the tide gauges the mean level of the sea to which the heights in the Bombay Tide Tables are referred.

I attach the statement marked A* of the heights as shown by the diagram (being the actual heights of the water as they occurred) compared with those given in the Tables. The high waters have only been compared, as of course we had no low water shown on the sheets, with the exception of 2 at the greatest neaps. The tank line represented our low water line.

Discrepancy of the Diagram and the Bombay Tide Tables.
* Not printed.

You will observe that the times of the high waters agree very well, but the heights are very much out in some cases.

Greatest discrepancy in time is	.. ..	42	minutes
Least " " "	.. ..	1	"
Average " " "	.. ..	14	"
Greatest " " height is	.. ..	0·88	foot
Least " " "	.. ..	0·00	"
Average " " "	.. ..	0·26	"

Statement marked B* shows the discrepancies of the records of the Aneroid barometers as read from each at 10 A. M. and 4 P. M. daily. Before commencing recording the readings for the trial month, I gave the value of each index error to the Sub-Surveyor in charge, and the figures in red in the daily reports (a set of which are herewith sent) show the corrected values. The index error was obtained by comparison with the mercurial barometer sent from Calcutta which had previously been compared with the standard barometer there.

Discrepancies of the Aneroids inter se.
* Not printed.

The greatest discrepancy between any two of the instruments was.		0·179	inches
The least was		0·023	"
The average		0·061	"

Statement C* shows the discrepancies of the Anemometers. You will observe that the greatest discrepancies for each day are noted in a column for the purpose.

Discrepancies of Anemometers.
* Not printed.

The greatest discrepancy of any day was	.. .. ..	1·40	miles
The least		10	"
The average of the daily discrepancies was	.. .. ..	5·4½	"

The directions recorded by each instrument are almost identical.

The party may now be said to be almost completely formed and consists of one Officer in charge, 1 Surveyor, 2 Native Sub-Surveyors and 5 Apprentice Sub-Surveyors, 1 Writer, 1 Recorder, 1 Hospital Assistant (not yet joined), 1 Mechanic and about 45 Khalásis and Peons. Mr. Bell joined the party lately from Mussoorie and during the short time he has been with me he has shown himself most useful in every way, and I have no doubt will give me valuable assistance in carrying on the operation.

Personnel of the Party.

Narsing Das Sub-Surveyor has also lately joined; the high character he has received from the officer under whom he has lately been serving, and the way in which he has worked since he joined me are sufficient grounds for considering him as likely to perform the duties entrusted to him in a satisfactory manner.

I have lately had some trouble with a Sub-Surveyor who resigned a few days ago. You have been pleased to accept his resignation, and I have engaged an observer from the temporary establishment of the Colaba Observatory on the same pay. He seems very intelligent and I have no doubt will soon pick up the duties in the Tidal Observatory.

The Apprentice Sub-Surveyors have given me every satisfaction and I think they have now a fair knowledge of their duties in the Tidal Observatories but notice of their services can only be taken in the next Annual Report,

It may not be out of place to state that I had considerable trouble in carrying on the work in Bombay. The machines having to be altered, air lodging in the bends of the connecting pipe, the stoppage of the clocks and the very bad state of some of the machines when received from England also the damage done by the monsoon to one of the Anemometers, breakage of the gold threads in the barometers, rats eating diagrams of the tide gauges, and ants getting into the clocks of the barometer, were all sources of considerable anxiety to me.

Trouble of generally carrying on the work in Bombay.

The printed forms from England for the reductions of the Tidal Observations by harmonic analysis have only lately been received; but even had they reached me early in the recess, I should have been unable to have commenced the reduction of the observations taken at Tuticorin in 1871-72 which you sent me some time ago. I had my time fully employed in looking after the work here, and I had no assistant until quite lately, for the Apprentice Sub-Surveyors were newly taken on, and had to work in the tidal observatories.

Inability to commence the reductions of the Tuticorin Observations.

My acknowledgements are due to Major Merewether R.E. the Executive Engineer of the Harbour Defence for the assistance he has rendered me from time to time here, and placing at my disposal the use of part of the Bunder, and generally in giving me the use of workshops in making up the equipment for the Tidal Observatories.

Assistance received from Harbour Defence Workshops.

Mr. Morris, the Mechanical assistant of the Harbour Defences, has been most obliging in every way, and has helped me in the construction of almost all the different stores for our use, in the alterations of the machines, and in fact throughout in many of the difficulties I had to contend with. During the time we had the trouble with the air getting into the connecting pipes, he took the most lively interest in helping me to overcome this obstacle and enabled me to get men to go into the water and raise the pipes at any time when required, and this had often to be done long before or after the usual working hours, to suit the tides.

Extract from the Narrative Report—dated 1st May 1873—of J. B. N. HENNESSEY, ESQ., Deputy Superintendent 1st Grade, G. T. Survey, in charge Computing Office.

Calculating Branch.

(3.) The numerous and not unimportant duties imposed by current demands are not susceptible of being presented in the form of a summary; an idea of their nature and extent can therefore be formed only from the statements which are hereafter given; but apart from these, it may be generally stated, that amongst the leading objects kept in view during the past year, the completion of Volumes III and IV of the Principal Triangulation and the reduction of the secondary operations, N. W. Quadrilateral, which are to appear in the Abstract volumes of the Great Trigonometrical Survey of India, are to be reckoned. Volumes III and IV are almost completely out of hand; so much so, that they may be said to await the services of the bookbinder, pending completion of the Reduction Chart (to illustrate these volumes) which is in course of being engraved at the Surveyor General's Office, Calcutta. And with regard to the Secondary Triangulation, it may perhaps be remembered, that in my last report, mention was made of a suitable process which I had devised for fitting in the Secondary Triangulation by a dispersion of angular errors where this procedure was considered desirable: the Secondary Series of the Great Arc and Great Indus, and a few on the Rahún and Karáchi, have been fitted in by this process.

Part of work summarized.

(4.) The details of the ordinary calculations are as follow:—

Ordinary calculations detailed.

Examination and Correction.

Angle Books	.. ..	1¼ Vols:	
Principal Triangulation.	Azimuths by Circumpolar Stars ..	40 Stations.	
Secondary Triangulation.	Log. Sines	280 Triangles.	
Do.	Log. Sides	2,553 „	(in duplicate)
Do.	Latitudes, Longitudes and Azimuths (single deductions)	162 Points.	

Computations in Duplicate.

Principal Triangulation.	Spherical Excess	21 Triangles.	
Do.	Weights	33 Angles.	
Do.	Azimuth by Circumpolar Stars ..	1 Station.	
Do.	Do. Level and Collimation Corrections	12 „	
Secondary Triangulation.	Traverse	32 Sets.	
Do.	Adjusted by Angular corrections ..	1,245 Triangles.	
Do.	Log. Sines	6,253 „	
Do.	Log. Sides	4,410 „	
Do.	Feet and miles	5,836 „	
Do.	Latitudes, Longitudes and Azimuths (single deductions)	3,920 Points.	
Explorations.	Co-ordinates of Route-Survey Khulm to Bokhara.		
Do.	Do. 141 other points.		
Do.	Latitudes by Circum-meridian observations ..	51 Points.	
Do.	Longitudes deduced from traverse	20 „	
Do.	Heights by Barometer	82 „	
Do.	do. Thermometer	108 „	

Calculating Branch.—(Continued.)

(5.) The work performed in connection with the Typographic and Photozincographic presses, I notice, as in my last report, under two heads.

For the volumes on the operations of the G. T. Survey, &c.	*Compiled or otherwise prepared.*
Principal Observed Angles	10 pages.
Azimuths observed to Circumpolar Stars	25 „
Principal Triangles. Great Indus Series	10 „
Do. Karáchi „	12 „
Do. Gurhágarh „	6 „
Do. Rahún „	6 „
Principal Latitudes, Longitudes, Azimuths and Heights. Great Indus Series	28 „
Secondary Triangles. Great Indus Series	23 „
Spirit-Levelled Heights. Tuticorin to Cape Comorin base-line ..	5 „
Do. Section IX, Season 1871-72 ..	19 „
Total ..	144 pages.

besides the above, 25 plates of figures for Volumes III and IV were roughly plotted for the guidance of the drawing branch.

Numerical Charts.	*Compilation of data for projection.*	
Budhon Series	Latitudes, Longitudes, Azimuths and Heights.	
Amúa „	Do.	
Rangír „	Do.	(in part)
N. W. Himalaya Series. Sheet No. 3	Do.	
Bombay Triangulation. Sheet No. 9.	Do.	

Reduction Chart of the N. W. Quadrilateral.

Numerical Charts.	*Compilation of data for press.*	
Budhon Series	Sheets	Nos. 1 to 4.
Amúa do.	Do.	Nos. 1 and 2.
Bombay Triangulation	Do.	No. 9.
Sutlej Series	Do.	Nos. 1 to 4.
Gurhágarh Series	Do.	Seasons 1860-61-62.
Description of Bench-Marks, &c., for Level Chart	Do.	No. 3.

the amount of compilation involved in above is estimated at 300 pages.

Numerical Charts.	*Compared.*
Amúa Series	2 sheets.
Budhon do.	4 „
Gora do.	1 „
Sutlej do.	4 „
Rahún do.	2 „
Gurhágarh do.	1 „
N. W. Himalaya Series	3 „
Bombay Triangulation	1 „
Assam Valley (1871-72)	1 „
Bider and Bilásphur do.	1 „
Bangalore N. Section do.	1 „
Bilásphur „ do.	1 „
Reduction Chart N. W. Quadrilateral	1 „
Total ..	23 sheets.

Examined.

Spirit-Levelled Heights by the Revenue Survey Department, for incorporation into Level Route Map of the Western Himalayas. [Sheets.
Index to Main Lines of Levels G. T. Survey.
Index to Preliminary Charts N. W. Quadrilateral.
Ditto N. E. do.

In addition to the foregoing, 1170 pages of proofs were read and compared twice, and 1029 pages of proofs were examined by a single reader and passed for the press,

Calculating Branch.—(Continued.)

Instrumental Work.

(6.) The 24-inch theodolite in use on the Brâhmaputra Series was cleaned and adjusted; and Captain T. T. Carter, R.E., was instructed in the departmental method of observing azimuths to Circumpolar Stars. Captain Chapman of the Yárkand Expedition was taught (by Mr. Cole) the use of the subtense theodolite, and the computation of Time, &c., from observations taken with this instrument. Captain H. Trotter, R.E., received instruction in the observation and computation of Lunar Zenith-distances for finding longitude; besides the discussion of various professional subjects, preliminary to his departure with the Yárkand Expedition. A ten-foot iron end-bar was constructed for the Executive Engineer Rânikhet division, and the length compared with the G. T. Survey Standard Bar **A**. The index errors of 18 boiling point thermometers were determined for the use of the explorers, whose surveying instruments were generally examined and put in order. Observations for Time were taken on 13 days and the results computed. Meteorological observations were made in Dehra observatory on every day of the year without exception; the daily results were reduced and communicated as usual, month by month, to the Reporter on Meteorology, N. W. Provinces, and a table of the monthly means is appended to this report.

Pendulum Observations.

(7.) Consequent on the appointment of Captain W. J. Heaviside, R. E., to the charge of the Pendulum party, he was instructed in the use of the transit instrument and the methods of making and computing observations with the pendulums of the Royal Society, processes which Captain Heaviside's skill and aptitude soon enabled him to master. He was also assisted in connection with three centigrade thermometers, and in preparing working tables of corrections for these thermometers and tables of differences of expansion between the Russian pendulums and their scale; besides such other questions as arose from time to time, on which my co-operation was desired. The services of a check computer were placed at his disposal for some 3 weeks to assist in the reduction of his observations, besides that 18 sets of the latter were reduced in the Computing Office under directions from the Superintendent.

Protection of Stations.

(8.) Replies to 280 letters, in connection with the protection of Stations, were drafted by Mr. C. Wood under the Superintendent's directions; and 32 supplementary and duplicate lists, including 118 stations were issued to district officers. These lists in the first instance are partially of a tentative nature; for, owing to modern alterations in the boundaries of districts, &c., it is only after due reference and correspondence that it can be settled in which of two contiguous districts a given station is situated. Speaking in this sense, 20 districts have been settled during the past year, making about 238 districts in all, which have been placed on this satisfactory footing; the corresponding check lists, including some 1,900 principal stations, have been disposed of to date.

Miscellaneous.

(9.) Some of the miscellaneous duties discharged are as follows.

Prepared:—three copies of Vocabulary of Indian names and words for office use; four Auxiliary tables for departmental use; Duplicate of pendulum observations at Dehra and Kalíána; Polymetrical tables for Major Montgomerie's route map; and tables of Latitude, Longitude and Height of points on the N. W. Frontier for Colonel Walker's Map of Turkestan, 2nd edition. Service books, 120 in number, were filled in at a cost of no little time and patience. The Cost book of the G. T. Survey was brought up for the year 1872-73, and it, together with the Budget comparison table, is now kept to date, monthly. The records of the Bombay Island survey were generally examined with a view to ascertaining their eligibility for incorporation with other materials. Compiled and passed through the press Introduction to Great Arc Series for Volume IV. Supplied data to 34 Executive Officers, involving a considerable amount of compilation and calculation. Accounts kept and monies disbursed to explorers, for a few weeks; translated their letters, &c., &c. To these may be added the investigation and detection of a mistake in the method of determining the percentage of error in certain traverses.

Typographic Branch.

(10) The work performed by the Printing Office since 1865-66 is concisely stated hereafter.

	1865-66	1866-67	1867-68	1868-69	1869-70	1870-71	1871-72	1872-73
Pages composed,	377	756	641	697	693	819	1,143	1,420
Do. printed,	53,329	93,411	126,696	155,025	106,231	234,828	241,348	273,157

Typographic Branch.—(Continued.)

the total pages composed last year may be subdivided under the following heads.

Observations and Calculations for the volumes of the Great Trigonometrical Survey in hand	..	787 pages.
Spirit-Levelled Heights	..	33 „
Data for Charts, Descriptions of Bench-marks, Routes, Professional Orders and Memoranda	..	483 „
Report to Government 1871-72	..	117 „
Total	..	1,420 pages.

Drawing Branch.

(11.) The work executed in the Drawing Office is exhibited in the table which follows this report.

Photozincographic Branch.

(12.) The work performed by the Photozincographic branch is given in the following tables, under the heads Maps, Numerical Charts, Diagrams and Forms.

Maps.

Subject	When published	No. of parts	No. of copies printed
Prints of maps published in former years	..	27	1,164
Index to Kashmir Triangulation Charts	June 1872	1	111
Spirit Levelling operations, No. 11	July „	1	100
Routes in Northern India, No. 1	„ „	1	115
Do. do. No. 3	„ „	1	108
Do. do. No. 4	August „	1	112
Do. do. No. 2	„ „	1	109
Index to Northern Portions of Bombay Triangulation.. ..	„ „	1	350
Do. Main Lines of Levels, G. T. Survey	„ „	1	381
Spirit Levelling operations, No. 10, 2nd edition	September „	1	105
Index to Main Lines of Levels, G. T. S. (reduced scale)	„ „	1	432
Routes in North-Western Himalayas (reduced scale) ..	October „	1	77
Index to Kattywar Survey	„ „	1	741
Do. Kumaon and Gurhwal Survey	November „	1	518
Do. Guzerat Survey	„ „	1	554
Trans-Frontier Map, No. 7 skeleton	December „	1	248
Kumaon and Gurhwal, sheet No. 2 skeleton	January 1873	1	104
Do. do. No. 2 contoured	„ „	1	112
Do. do. No. 18	„ „	1	109
Do. do. No. 23 contoured	„ „	1	105
Do. do. No. 32 do.	February „	1	105
Dingri Maidan	„ „	1	570
Trans-Frontier Map, No. 4	„ „	1	60
Kumaon and Gurhwal, sheet No. 17 skeleton	March „	1	100
Spirit Levelling operations, No. 8	„ „	1	105
Kattywar, sheet No. 25	April „	1	105
Turkestan Map, sheet No. 1 (2nd edition)	„ „	1	210
	Total ..	53	6,910

Numerical Charts.

Kashmir Triangulation, No. 5	June 1872	1	70
Do. do. No. 7	„ „	1	75
Bangalore Meridional Series, S. section, Season 1870-71 ..	„ „	1	65
Rahún Series, Season 1856-57	July „	1	25
Do. do. 1852-53	„ „	1	66
Bider Longitudinal Series, Season 1870-71	„ „	1	70
Kashmir Triangulation, No. 1	August „	1	70
Do. do. No. 8	„ „	1	66
Do. do. No. 6	„ „	1	68

Photozincographic Branch.—(Continued.)

Numerical Charts.—(Continued.)

Subject	When published	No. of parts	No. of copies printed
Kashmir Triangulation, No. 10	Septer. 1872	1	62
Do. do. No. 9	„ „	1	65
Sutlej Series, No. 1	October „	1	65
Kashmir Triangulation, No. 2	„ „	1	65
Assam Valley Triangulation, Season 1871-72	„ „	1	65
Sutlej Series, No. 2	November „	1	65
Kashmir Triangulation, No. 4	„ „	2	67
Do. do. No. 3	„ „	2	65
Rahún Series, Season 1856-57 (2nd edition)	December „	1	65
Sutlej Series, No. 3	„ „	1	66
Rahún Series, Season 1855-56	„ „	1	65
Sutlej Series, No. 4	January 1873	1	67
Biláspur Series, N. section, Season 1871-72	„ „	1	65
Northern Portions of Bombay Triangulation, No. 9	„ „	1	66
N. W. Himalaya Series, No. 3	„ „	1	67
Bider Longl. and Biláspur Meridl. Series, Season 1871-72	February „	1	65
Gurhágarh Series, Season 1860-61	„ „	1	66
Budhon Series, No. 2	„ „	1	65
Do. do. No. 4	„ „	1	65
N. W. Himalaya Series, No. 1	„ „	1	66
Do. do. No. 2	„ „	1	63
Budhon Series, No. 1	March „	1	65
Do. do. No. 3	„ „	1	64
Gora Series, No. 2	April „	1	65
Bangalore Meridional Series, N. Section, Season 1871-72	„ „	2	67
	Total ..	37	2,206

Diagrams.

Subject	When published	No. of copies printed
Diagrams of Bench-Marks and Plates of Figures to illustrate Vols. III and IV,	May 1872	931
	June „	1,317
	July „	640
	August „	190
	September „	515
	October „	478
	November „	448
	December „	529
	January 1873	1,247
	February „	2,862
	March „	1,752
	April „	1,146
	Total, ..	12,055
Professional and Office Forms, ...	1872-73	12,549

Photozincographic Branch.—(Continued.)

5,634 Maps and 3,254 Charts were issued during the year. The forms were expended, as usual, as fast as they could be printed. Contrasting the work performed since 1870-71, we have

Year	Maps	Charts	Diagrams	Forms
1870-71	6,465	839	13,205	10,482
1871-72	10,131	1,375	4,937	13,655
1872-73	6,910	2,206	12,055	12,549

An Abstract of the work executed since 1866-67 stands as follows.

Subject	Number of Prints						
	1866-67	1867-68	1868-69	1869-70	1870-71	1871-72	1872-73
Maps, Charts and Diagrams,	7,118	7,376	5,538	12,315	20,509	16,443	21,171
Forms, ...	5,152	10,531	10,800	13,571	10,482	13,655	12,549

thus in 1866-67 the total of the prints was 12,270; in 1872-73 this total was 33,720; in other words the work has nearly trebled in 6 years; in fact, the value of the process cannot be ranked too high.

(13.) I conclude my report for the year 1872-73 by noticing the conduct of the assistants placed under my care.

Mr. W. H. Cole, M.A., continues to be the excellent assistant I have always found him; his natural abilities are now all the more valuable that his experience is growing matured, and these combined with his patience and good temper enable me to leave many a subject to his entire control.

Calculating branch.

In all the details of my duties, I could wish for no more efficient assistant than Mr. Charles Wood: he continues active, willing and quick in detecting mistakes. Mr. H. W. Peychers is fast becoming a very useful hand, and I have good reasons to be satisfied with his conduct. Baboo Gunga Pershad maintains the excellent opinion I have frequently expressed of him; in addition, his patience and care in going through the tedious process of training new computers are commendable. Baboo Cally Mohun Ghose has, I am glad to say, paid more attention to practical matters, by which his general attainments, which are good, promise to be enhanced. Baboo Kally Coomar Chatterjee continues to be accurate, painstaking and trustworthy. Nothing could exceed Baboo Gopal Chunder's care, and were it only possible to induce him to "put on a little more steam," his value would be increased; he takes care of the records to my satisfaction, besides discharging the duties of a computer. Baboo Tarapodo continues steady and useful. Of the new hands, Mizaji Lal makes himself generally useful, a most desirable trait, which Shoshee Bhooshun Shome seems inclined to follow. The other new hands are sufficiently promising to admit of the hope that I may be able to notice them by name next year.

Photozincographic branch.

Mr. Ollenbach continues hardworking, painstaking and neat fingered: he works with undiminished interest, and I hope to be able to add, that his methodical procedure is equal to his zeal. Mr. Dyson is the same cheerful, ready hand as ever.

Printing branch.

Mr. O'Connor is zealous and generally efficient as I have always been able to report of him: he would add to my peace of mind could he but induce his compositors and pressmen not to transplant blunders into proofs, where accuracy prevailed before.

Drawing branch.

Mr. Atkinson has now discharged his new duties as Chief Draftsman for more than a year, and promises to prove equal in accuracy, method and management to the requirements of his place. I trust in due course to be able to report, that by dint of careful study and reflection, Mr. Atkinson maintains his knowledge of geographical subjects up to date, as well as manages and improves the promising assistants under his charge. Shaikh Saidoodeen Hoosain continues to be one of the neatest of draftsmen, besides that his knowledge of events and records in the drawing office makes him generally useful: the other draftsmen have given me satisfaction, and of the assistant draftsmen Shamlal and Poorno Chunder promise to become excellent hands.

MONTHLY Meteorological results taken from the Register kept at the Office of the Superintendent G. T. Survey of India, Dehra Doon.

YEAR & MONTH.	BAROMETER. At h. m. 9 30 A. M. Highest.	Lowest.	Monthly Mean.	At h. m. 3 30 P. M. Highest.	Lowest.	Monthly Mean.	HYGROMETER (monthly mean) At h. m. 9 30 A. M. Temperature of Dew point.	Humidity.	At h. m. 3 30 P. M. Temperature of Dew point.	Humidity.	THERMOMETER. Dry Bulb. Max: reading in Sun's rays.	Min: reading on grass.	Max: reading in air.	Min: reading in air.	Monthly Mean in air	WET BULB. Max: reading Wet.	Min: reading Wet.	Monthly Mean: Wet.	WIND. Average direction.	Monthly Mean force in lbs. per square foot.	CLOUD. Monthly Mean At 9 30 A. M.	Monthly Mean At 3 30 P. M.	RAIN. Number of days it fell.	Fall in inches.
1872	in.	in.	in.	in.	in.	in.	°		°		°	°	°	°	°	°	°	°						
January	27·902	27·681	27·804	27·809	27·602	27·716	47·0	·782	47·7	·599	79·0	31·1	70·6	36·3	55·2	64·7	33·1	48·0	N.	·00	6	5	9	6·58
February	·842	·630	·744	·799	·576	·659	44·7	·668	42·4	·435	91·7	33·7	78·4	36·0	57·0	63·8	32·1	47·8	W.	·00	4	5	6	2·25
March	·868	·518	·694	·758	·468	·611	53·4	·551	50·2	·355	100·6	45·3	90·4	50·3	69·9	67·4	43·2	56·1	W.	·00	2	3	3	·55
April	·815	·474	·613	·677	·404	·534	54·8	·470	53·0	·355	106·5	49·1	92·8	54·0	74·0	76·0	47·6	56·2	W.	·01	3	4	4	1·28
May	·614	·380	·499	·551	·303	·424	59·7	·437	57·4	·326	110·9	57·0	99·7	61·8	81·7	77·0	48·5	64·1	N.	·00	2	2	4	1·36
June	·528	·232	·400	·444	·180	·329	70·2	·619	69·5	·548	114·4	68·3	102·8	70·9	84·3	80·2	55·4	71·4	W.	·00	4	4	13	12·03
July	·541	·293	·406	·486	·244	·341	74·8	·837	75·2	·831	103·3	65·9	88·7	69·8	79·4	84·7	62·2	73·0	N.	·00	7	8	25	31·80
August	·615	·326	·424	·523	·259	·347	75·3	·877	76·7	·828	101·5	69·6	89·4	71·0	79·3	81·8	61·7	73·4	W.	·00	8	8	28	22·74
September	·639	·450	·562	·598	·381	·476	71·9	·826	73·5	·785	103·8	60·8	88·8	62·9	76·7	80·2	56·4	70·3	N.	·00	4	6	18	14·79
October	·807	·531	·691	·725	·461	·600	59·3	·625	60·3	·517	99·9	50·8	86·0	53·1	70·8	75·5	43·9	60·2	N.	·00	0	1	0	·00
November	·833	·682	·787	·766	·617	·699	50·4	·584	50·5	·435	92·4	42·0	81·8	44·8	64·2	65·5	38·2	53·0	N & W.	·00	1	1	1	·12
December	·983	·664	·785	·903	·585	·695	48·7	·715	49·1	·496	86·9	40·0	74·6	42·8	58·7	62·6	37·5	50·0	N.	·00	1	2	1	·20

ABSTRACT OF RAIN-FALL AT DEHRA DOON G. T. SURVEY OFFICE FROM 1861 TO 1872.

MONTH.	1861. Inches.	1862. Inches.	1863. Inches.	1864. Inches.	1865. Inches.	1866. Inches.	1867. Inches.	1868. Inches.	1869. Inches.	1870. Inches.	1871. Inches.	1872. Inches.
January, ...	———	———	3·31	·36	1·93	———	1·25	2·69	1·67	·04	·46	6·58
February, ...	———	———	·00	2·18	6·48	———	1·46	7·28	1·43	1·39	2·54	2·25
March, ...	———	———	1·69	·52	4·67	———	1·43	1·74	7·25	4·13	·00	·55
April, ...	———	———	·33	·21	1·35	2·50	·74	·84	·11	1·84	·43	1·28
May, ...	———	———	·34	2·53	6·45	———	3·21	·82	·00	·31	3·44	1·36
June, ...	12·19	———	12·19	·29	2·10	8·21	9·94	6·83	2·96	7·04	24·34	12·03
July, ...	24·53	28·66	36·96	37·60	19·12	34·75	28·69	21·26	20·66	33·05	36·32	31·80
August, ...	54·75	45·22	24·78	22·50	29·40	23·70	23·63	12·85	16·79	28·45	38·39	22·74
September, ...	9·31	20·20	2·19	7·21	10·06	5·60	3·81	3·02	22·56	13·78	11·03	14·79
October, ...	·02	5·52	·60	1·68	·00	·20	·93	·05	2·39	1·39	·00	·00
November, ...	·01	·00	·92	·17	·00	———	·00	·00	·00	·00	·00	·12
December, ...	·00	·00	·60	·03	4·02	———	·00	·18	1·22	·01	1·32	·20
Total, ...	100·81	99·60	83·91	75·37	85·58	74·96	75·09	57·56	77·04	91·43	118·27	93·70

NOTE.—Where blanks occur no record is forthcoming. Height of Barometer Cistern above Mean Sea Level, 2232·41 feet.

Annual Return of amount of Work executed in the Drawing Branch of the Office of Superintendent G. T. Survey, from 1st May 1872 to 30th April 1873.

DESCRIPTION OF WORK.	Number of sheets or diagrams. Finished	In hand	Scale 1 inch =	REMARKS.
Compilation			Miles.	
Map of Turkestan in 4 sheets, 2nd edition	4		32	For Photo-zincography.
Sheet No. 4 Northern Trans-British Frontier	1		16	ditto.
Do. No. 7 ditto ditto ditto	1		16	ditto.
Do. No. 4 Map of Routes in Northern India	1		16	ditto.
Map of the Dingri Maidan and Upper Arun River	1		8	ditto. Reduction to ½ scale
Sheet No. 6 of Spirit-Levelled Heights		1	2	ditto.
Do. No. 8 ditto ditto	1		2	ditto.
Do. No. 10 ditto ditto (2nd edition)	1		2	ditto.
Do. No. 23 ditto ditto	1		2	ditto.
Do. No. 26 ditto ditto		1	2	ditto.
Section IX of Spirit Levelling Operations 1871-72, to illustrate Book of Heights	1		20	ditto.
Index Map to Main Level Lines of the G. T. Survey ...	1		40	ditto. ditto.
Index Charts				
Kashmir Triangulation	1		32	ditto.
Northern Bombay Triangulation	1		16	ditto. ditto.
Preliminary Numerical Charts of the N. W. Quadrilateral ...	1		32	ditto.
Final Numerical Charts of the N. W. Quadrilateral	1		32	ditto.
Preliminary Numerical Charts of the N. E. Quadrilateral ...	1		32	ditto.
Final Numerical Charts of the N. E. Quadrilateral	1		32	ditto.
Preliminary Numerical Charts				
Kashmir Triangulation, Sheet No. 7 (projected by Mr. W. G. Boverley)	1		4	ditto.
N. W. Himalaya Series, Season 1851-52, (in 2 sheets)	2		4	ditto.
Budhon Meridional Series, Nos. 1 to 4	4		4	ditto.
Rahún ditto ditto, Season 1855-56, and 1856-57 (redrawn)	2		4	ditto.
Gurhágarh ditto ditto ditto 1860-61 (redrawn), and 1861-62	2		4	ditto.
Biláspur ditto ditto ditto 1871-72 Northern Section	1		4	ditto.
Assam Valley Triangulation, Season 1871-72	1		4	ditto.
Rangir Meridional Series, Nos. 1 to 3		3	4	ditto.
Bidar Longitudinal and Biláspur Meridional Series, Season 1871-72	1		4	ditto.
Bangalore Meridional Series, Season 1871-72, Northern Section	1		4	ditto.
Amún ditto ditto, Nos. 1 and 2	2		4	ditto.
Northern Bombay Triangulation, Sheet No. 9	1		4	ditto.
Gora Meridional Series, Nos. 1 and 2	2		4	ditto.
Final Numerical Charts				
Great Arc Series (Principal Triangulation), Nos. 1 to 6		6	4	ditto.
Karáchi Longitudinal Series (ditto) Nos. 1 to 5		5	4	ditto.
Plates.				
Of Figures to illustrate Volumes III and IV of the operations of the Great Trigonometrical Survey of India	25			ditto. ditto.
Miscellaneous.				
Colored 8,413 copies of maps, and performed numerous other miscellaneous duties.				

GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1873-74,

Prepared for submission to the Government of India.

BY

COLONEL J. T. WALKER, R.E, F.R.S., &C.,

SUPERINTENDENT OF THE SURVEY.

Dehra Dun:

PRINTED AT THE OFFICE OF THE SUPERINTENDENT G. T. SURVEY.

M. J. O'CONNOR.

1874.

BOMBAY BRANCH
OF THE
Royal Asiatic Society.
CLASS

BAY OF BENGAL
INDEX CHART
TO THE
GREAT TRIGONOMETRICAL SURVEY
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GREAT TRIGONOMETRICAL SURVEY OF INDIA
IN 1873-74.

The following is a summary of the several operations of the year under review, given in the order in which they will be found described in this report.

			Described at pages of the Report.	Described at pages of the Appendix.
I.	*Trigonometrical.*	The Southern Section of the Bangalore Meridional Series.	6	3—a
II.	*Trigonometrical.*	The Operations in the Assam Valley. ...	8	7—a
III.	*Trigonometrical.*	The Brahmaputra Series, Meridian 90°. ...	9	10—a
IV.	*Trigonometrical.*	The Jodhpúr Series, Meridian 72½°. ...	11	12—a
V.	*Trigonometrical.*	The Eastern Frontier Series, in Burma. ...	12	15—a
VI.	*Spirit Levelling.*	In the Madras Presidency. ...	14	19—a
VII.	*Topographical.*	The Survey of Kattywar. ...	15	21—a
VIII.	*Topographical.*	The Survey of Guzerat. ...	16	27—a
IX.	*Topographical.*	The Surveys in Dehra Dún. ...	20	36—a
X.	*Topographical.*	Himalayan Surveys in Kumaun and Garhwál. ...	23	42—a
XI.	*Tidal Observations.*	Determinations of mean-sea level in the Gulf of Kutch.	23	45—a
XII.	*Geodetic.*	The Pendulum Operations. ...	30	53—a
XIII.	*Geographical.*	Trans-Himalayan Explorations. ...	33	Second appendix
XIV.	*Computing Office.*	Examination and final reduction of the observations, and publication of the results.	35	59—a
XV.	*Cartography.*	Preparation and publication of various Charts and Maps.	36	66—a

(2.) The operations carried out during the year under review have produced the following out-turn of work;—of Principal Triangulation, with the great theodolites of the Survey, 70 triangles, embracing an area of 7,190 square miles, and disposed in chains which, if united, would extend over a direct distance of 302 miles, and in connection with which 3 astronomical azimuths of verification have been measured;—of Secondary Triangulation, with vernier theodolites of various sizes, an area of 5,212 square miles has been closely covered with points for the topographical operations, an area of 3,650 square miles has been operated in *pari passu* with the principal triangulation but exterior thereto, and in an area of 12,000 square miles—in the ranges of mountains to the north of the Assam Valley which are inhabited by independent tribes—a large number of peaks have been fixed, many of which have already been found serviceable in the geographical operations now being carried on with the Military Expedition against the Dufflas;—of Topographical Surveying, an area of 534 square miles has been completed in British portions of the Himalayas, on the scale of one inch to the mile, an area of 2,366 square miles in Kattywar on the two-inch scale, and areas of 690 and of 63 square miles respectively, in Guzerat and in the Dehra Dún, on the scale of 4 inches to the mile;—of Geographical Exploration, much valuable work has been done in Kashgharia and on the Pamir Steppes, in connection with Sir Douglas Forsyth's mission to the Court of the Atalik Ghazi, and several additions to the geography of portions of Great Thibet and of Nepaul have been obtained through the agency of native explorers.

(3.) The principal triangulation has been executed with the great theodolites, whose azimuthal circles have a diameter of 24 inches and are read by 5 equidistant microscopes. The average theoretical 'probable error' of the angles, as deduced from the observations, and the average geometrical error of the triangles—or the amount by which the sum of the three observed angles of each triangle differs from 180° + the spheroidal excess—are shown in the table given in the margin. In the course of the operations of the present year the northern section of the Brahmaputra Meridional Series has been completed, whereby two important circuits of triangulation formed by it with the Assam and East Calcutta Longitudinal Series to the north and south, the Calcutta Meridional and the Eastern Frontier Series to the west and east, have been closed. The Straits of the Gulf of Manaar have been reconnoitered, with a view to connecting the triangulation of India with that of Ceylon, which has been found to be feasible.

Series.	Probable Errors of Observed Angles.		Geometrical Errors of Triangles.	
	Number.	Amount.	Number.	Amount.
I	60	±0″·14	20	0″·40
III	42	·25	14	·83
IV	78	·14	26	·14
V	30	·54	10	·70
Average,...	...	±0″·22	...	0·43

(4.) But the most important features in the operations of the principal triangulation of the present year are the resumption of the chain of triangles in Burma, and the completion of the Bangalore Meridional Series, for the revision of the southern section of the Great Arc. The triangulation in Burma was suspended in 1870, during the financial difficulties of the Government, for reasons which are set forth in my Report for 1869-70; it is now urgently required, in order to furnish a basis for topographical and revenue survey operations which are about to be commenced in Burma; but to enable it to be undertaken without increasing the normal expenditure of this Department, one of the parties employed on the principal triangulation has been broken up, and thus instead of the *five* parties so employed last year there have only been *four* this year. The completion of the revision of the Great Arc concludes the revisionary operations for certain important triangulations which were originally executed at the commencement of the present century with very inferior instruments, and are specified in my Report for 1864-65 as requiring to be repeated with the best modern appliances; thus I have now much gratification in expressing my conviction that no portion of the principal triangulation remains which will ever require to be

revised, and that the last of the old links, in all the great chains of triangles, which might with any reason have been objected to as weak and faulty, have now been made strong and put on a par with the best modern triangulation.

(5.) The pendulum observations have been completed, and the final results are now being computed and prepared for publication.

(6.) Considerable assistance has been rendered to Colonel Tennant in the operations connected with the observations of the Transit of Venus; several astronomical instruments have been lent to him, and the services of an officer of this Department, Captain Campbell, R.E., have been placed at his disposal for an entire year. The Transit was independently observed by Mr. Hennessey at Mussooree, near the Office at which the Head Quarter's of this Survey are established during the recess season; Mr. Hennessy's account of his observations is given at the end of the first appendix to this report.

(7.) Owing to the absence of Captain J. Herschel R.E., from India, and to the services of Captain Campbell having been placed at Colonel Tennant's disposal, the operations for astronomical determinations of latitude, and astro-telegraphic determinations of differences of longitude, have been suspended.

(8.) The operations for determining the tidal constituents at certain stations in the Gulf of Kutch, with a view to the investigation of the supposed variations in the relative levels of the land and sea, have been fairly initiated, as will be reported on in full detail in Section XI.

(9.) The final reduction of the triangulation and of the pendulum operations, the preparation of the results for publication, and the printing of such results as are prepared, have made good progress, though not as great as I could have wished, owing to so much of my time having been taken up with other matters that I have frequently been obliged to set aside my own share of the work for months together.

(10.) During the recess of 1874, the Surveyor General, Colonel Thuillier C. S. I., went to England for three months, and I was directed to officiate for him in addition to performing my own duties. It so happened that just at that time I was called on, as officiating Surveyor General, to report on several matters of great importance, *viz.*, the results of the recent reorganization of the several branches of the Survey Department, working under the direct orders of the Government of India, which had been carried out with effect from the commencement of the financial year 1874-75; the reorganization of the Madras Revenue Surveys, with a view to arranging for the preparation of complete maps of the Madras Presidency by topographical surveys of the unsurveyed tracts lying between the revenue paying districts; the Cadestral Surveys in the North West Provinces, &c. These duties absorbed almost the whole of my time while I was acting for Colonel Thuillier, and have led to correspondence which has taken up much of it since his return; but as the subjects under discussion will presumably be dwelt on in his Administration Report for the present year, any further notice of them here is unnecessary.

(11.) I have also had to render assistance to Captain Bailey, R.E., the Superintendent of the newly formed Department of Forest Surveys, in organizing his establishments and training them in such a manner that their work may, on the one hand, satisfy all the requirements of their own department, for the purposes of forestry, and on the other hand be so conducted as to be suitable for combination with the operations of this Department. There were large tracts of forest in the Dehra Dún which required to be surveyed by the Forest Department, and Captain Bailey was directed to commence his operations by surveying them, as they are situated within a convenient distance of my Head Quarters. The additional trouble which this has caused me has not been little, but it has been more than repaid by the pleasure I have experienced in assisting an officer so anxious to learn all that is needed to enable him to do his work thoroughly well, as is Captain Bailey.

(12.) I now proceed as usual to describe the operations of the several Survey Parties and Offices. Further details, and accounts of various matters of

general interest, which have been brought to notice during the year, will be found in the first appendix, which gives "Extracts from the Narrative Reports of the Executive Officers"; while the second appendix gives accounts of certain Trans-Himalayan Explorations, in Great Thibet, &c., the details of which have not yet been published.

NO. I.—TRIGONOMETRICAL.

THE SOUTHERN SECTION OF THE BANGALORE MERIDIONAL SERIES.

(13.) Of the southern portion of the Great Arc—the portion situated between the parallels of 8° and 18°, which was measured by Colonel Lambton at the commencement of the present century—a revision has long been deemed an essential desideratum for geodetic purposes, and the execution thereof has been regarded as an object to be carried out whenever the general triangulation of the country had sufficiently approached completion to permit of the employment of one of the trigonometrical parties thereon; the revision has been proceeded with from time to time of late years, by triangulations emanating from the Bangalore base-line, which were carried on whenever opportunity offered, so that at the commencement of the present year about five-sixths had been revised; the gap remaining to be finished lay near the Cape Comorin base-line and was about 108 miles in length. This gap has now been completed by Major Branfill and his assistants; and thus the triangulation of the entire arc, from Cape Comorin to the Himalayas, has at last been brought to the same standard of accuracy as that secured for the northern section, by the operations of Colonel Everest, in 1833-41.

PERSONNEL.

Major B. R. Branfill, Dy. Supdt. 2nd Grade.
Mr. G. Belcham Asst. Sur. 1st Grade.
Mr. C. D. Potter " " "
" J. Bond " 3rd "
" E. W. Laseron " 3rd "

(14.) The revision was last taken in hand in the year 1870-71, when it was brought down from the north to the Palanei mountains, which flank the great plain of Coimbatore. Here great difficulties were met with in extending the triangulation southwards, in a symmetrical manner; the country had to be minutely examined, and many a promising design had to be abandoned before a practicable one was discovered. Colonel Lambton had met with similar difficulties, and they had baffled all his attempts to secure a station of observation at an obligatory point on the Palanei mountains, and he had been obliged to content himself with erecting a flag on that point—the Permaul Hill—and taking observations to it from the surrounding stations, and thus he was only able to measure two of the three angles in all the triangles (five in number) of which it forms a station. In the present instance the difficulty was surmounted, but only by giving one of the triangles a side of which the length is 64 miles, exceeding the longest side of any principal triangle yet measured in India; on so long a side observations can only be taken when the atmosphere is unusually clear, and this was fortunately the case when Major Branfill commenced operations this year, though when he first attempted the observations, at the end of the season of 1870-71, the atmosphere was unfavorable and he was compelled to return to his recess quarters leaving the work incomplete.

(15.) The operations of this year were intended to close on a side of the polygon around the Cape Comorin Base-line which had been completed in 1868-69, immediately after the measurement of the base-line; but it was found that one of the two stations on the side of junction had disappeared. This station was situated on a remarkable group of Red Sand Hills, where, in 1808, Colonel Lambton had constructed a station by driving long pickets into the drift sand; in 1869 Major Branfill, finding no trace of these pickets, had caused a masonry well to be sunk to a depth of ten feet, where it reached what was believed to be firm soil below; but during the interval of 4 years this well had been undermined,

G. G. Demoyer, Photo.

C. G. Ollenbach, Zinco.

Photozincographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Doon, August 1874.

and nothing remained thereof but some scattered *debris*. It would appear that the sand hills travel progressively in the direction from west-north-west to east-south-east, which is that of the prevailing winds in this locality; if Colonel Lambton's station was situated on the highest point of the hills and in a similar position relatively to the general mass as Major Branfill's, then the hills must have travelled a distance of about 1,060 yards to the E.S.E., for the results of the triangulation show that this is the distance between the positions of the two stations; thus the rate of progression would be about 17 yards per annum. From Major Branfill's Notes on the Tinnevelly District, which are appended to the General Report for 1868-69, it appears that certain measurements of the eastward drift had made it as much as 440 yards in the four years 1845-48; but the distance between the trigonometrical stations of 1808 and 1869 probably affords the most accurate measure which has hitherto been obtained of the rate of progress of this remarkable sand-wave, which gradually overwhelms the villages and fields it meets with in its course, and has never yet been effectually arrested; numerous attempts have been made, by growing grass and creepers and planting trees on the sands, to prevent the onward drift, but they have hitherto been unsuccessful.

(16.) During the field season Mr. Bond had the good fortune to encounter a couple of the wild folk who live in the hill jungles of the Western Ghâts; he has written an interesting description of them, which will be met with in the extracts from Major Branfill's report, at page 5—$_a$ of the first of the appendices to this report.

(17.) On the completion of the principal triangulation, Major Branfill proceeded to the Straits of Manaar, with a view to ascertain the practicability of carrying a triangulation across them, to connect the survey of India with that of Ceylon; the connection was found to be feasible, and the sketch facing this page was prepared by Major Branfill to show how it may be accomplished. The Straits were first examined at Adam's Bridge, where they are narrowest; but the islets composing the bridge were found to be sand-hillocks which for the most part are covered by the sea at high-water, and are only accessible at low-water during fine weather; they are thus most unpromising positions for the construction of suitable stations, and it was soon found necessary to abandon all idea of crossing over them. Higher up, on the line between Ramesweram and Jaffna, there are several islands which are composed of coral and sandstone and on which stations can therefore be erected. Of these the nearest to the Indian coast is Kachi-tivu, a small island not more than a mile in diameter, but standing well out of the water, and visible from the island of Ramesweram on one side and that of Neduven-tivu on the other; here it will be quite feasible to construct two stations—which need not be high ones—at a distance of about a mile apart, and to fix their positions by observations at them and at the Ramesweram stations; they will then serve as a base from which to determine the positions of the two next stations, which will have to be erected at the extremities of the island of Neduven-tivu. This island belongs to Ceylon and is about 7 miles in length; it is covered with a dense growth of palm trees, and the Ceylon Government has undertaken to construct towers of a sufficient height to overlook these trees, and to command the requisite view all round, and serve as stations of the triangulation. It has been proposed that the positions of these towers, as well as of the stations on the island of Kachi-tivu, should be fixed from the side of India by Major Branfill, with one of the first class theodolites of this Survey, as the acuteness of several of the angles which are involved in the triangulation necessitates the employment of the best instruments which can be provided for the measures of the angles, and the instrumental equipment of the Indian Survey is much superior to that of Ceylon; on the other hand the more symmetrical triangles, beyond the towers on Neduven-tivu, will be measured by the officers of the Ceylon Survey. Colonel Fyers, R.E., the Surveyor General of Ceylon, has taken great interest in the proposed operations, and done all in his power to co-operate with me in the matter; and arrangements are now being made by Mr. Twynam, the Government Agent of the Northern Province of Ceylon, who resides at Jaffna, for the construction of the two towers on Neduven-tivu.

(18.) On the completion of his reconnoissance of the Straits, Major Branfill proceeded to lay out a longitudinal chain of triangles on the parrallel of 9° 15′, which will run eastwards from the Great Arc to the coast, and thence across to Neduven-tivu, and from which a chain of triangles must eventually be carried up the Coast of Coromandel to Madras.

(19.) The general out-turn of work has been excellent. The principal triangulation, by which the revision of the Great Arc has now been completed, extends over a direct distance of 108 miles, is polygonal throughout, and covers an area of 3,239 square miles. Star observations, for determining the azimuth, were taken at a station at which the latitude had been determined astronomically by Captain Herschel, and pendulum observations had been made by the late Captain Basevi. An important chain of secondary triangles, 62 miles in length, fixing 51 secondary points, some of which are high and important hill peaks, was executed, in continuation of a series which had been commenced at Mangalore, and carried down the Malabar Coast for some distance, and was then diverted eastwards and brought through the Pálghát gap in the Western Ghâts, and has now been made to close on the triangulation in Coimbatore.

(20.) On returning to recess quarters Major Branfill and his assistants took in hand the reduction of the observations and the calculations of the usual preliminary results. The difference between the measured value of the base-line at Cape Comorin and the computed value brought down by the triangulation from Calcutta, *viâ* Madras and Bangalore, was found to be barely appreciable, being slightly more than a quarter of an inch in 1·7 miles, or more exactly 2·23 millionth parts of the length measured. Geodesists will be gratified to learn that no serious errors have been met with in the values of the three sections of the Great Arc comprised between the parallels of 8° 9′ and 18° 3′, which were deduced from Colonel Lambton's observations at the commencement of the present century; the final values will be greater, in each section, than those hitherto adopted, but probably by not more than 160 feet in any section, nor than 320 feet in all.

(21.) Major Branfill's duties during the recess have been much increased by his having had to take temporary charge of the two extra parties at Bangalore, during the absence of the officers in permanent charge who had been transferred elsewhere, and pending the arrival of other officers to take their places. I have much reason to be satisfied with the excellent manner in which Major Branfill performs every duty assigned to him, the interest he takes in all parts of his work, the training he gives to his assistants, and the constant supervision which he exercises over them.

NO. II.—TRIGONOMETRICAL.

THE OPERATIONS IN THE ASSAM VALLEY.

PERSONNEL.

W. G. Beverley Esq. Offg. Assistant Superintendent 1st Grade.
Mr. G. A. Harris Surveyor 4th Grade.
Mr. W. G. O'Sullivan Surveyor 4th Grade.
Mr. J. O. Hughes Assist. Surv. 4th Grade.

(22.) A full account of the history of these operations, and the difficulties which have been met with in their prosecution and have so greatly retarded their progress, was given in my report for last year. In the present year the triangulation has been advanced a distance of 47 miles, through the forest clad plains on the south bank of the Brahmaputra river, the operations terminating within a few miles of the Civil Station of Sibságar.

(23.) The amount of progress made would be considered small in most parts of India, but for this difficult country, where every line has to be cleared of trees and thick jungle with great labor, and the population is so scanty that laborers are rarely met with on the spot and have usually to be imported from a

distance, and where food for the surveyors and laborers and materials for the construction of the stations have also to be imported from a distance, it is as much as could well be expected, and it is materially greater than the progress which was made in either of the two preceding years.

(24.) Considerable advantage was derived from a modification in the construction of the stations which I had directed Mr. Beverley to introduce; instead of the usual central masonry pillar for the theodolite, surrounded by a platform (generally of solid earth work) for the observer, both raised to a sufficient height to overlook all irremoveable obstacles in the lines, a small pillar has been built, which is merely sufficient to indicate the site of the station permanently, and over it a tripod stand has been erected for the theodolite; the stand is formed of three stout logs firmly braced together, with the ends buried in the ground, and it is made sufficiently high to give the required command; around and isolated from it, a platform is constructed, of bamboos or timber, for the observer; these have been found to suffice very well for all practical requirements, and Mr. Beverley reports that "from the rapidity with which they can be constructed they have helped materially to advance the survey". Hitherto the signals under observation have also been set up on these tripods; but as their mounting does not require to be as firm and rigid as that of the theodolites, I have directed a further modification to be introduced in the construction of the stations, whereby the signals will be set up at a considerable height above the theodolites, and will thus be visible over the top of the long grass and jungle, the clearance of which has usually been found to be a very formidable task; I trust that this expedient will be found practicable, and that in future the line clearing will be restricted to the cutting down of such trees as are too high to be looked over.

(25.) During the season Mr. Beverley was able to fix several additional points in the Duffla Hills to the north of the valley, which will be most valuable aids to the officers who have been attached to the Duffla Expedition in order to make a survey of the country. A number of points were also fixed on the Naga Hills, to the southeast, which should be of much value to the officers now engaged in making a topographical reconnoissance of those hill tracts. Connections have also been made with the stations of the Revenue Survey in the valley. The aggregate length of the lines which had to be cleared, in course of the construction of the principal chain of triangles, was 178 miles.

(26.) Towards the conclusion of the field operations Mr. G. A. Harris was compelled by failing health to return to the recess quarters at Shillong; he had suffered much from fever, against which he struggled bravely, remaining in the field—far from medical aid—longer than he should have done, in order to complete his share of the operations; at last he was obliged to desist from work and to return to Shillong, where he died a few days after his arrival. He was a very painstaking and worthy member of the Department, and his loss is much regretted.

NO. III.—TRIGONOMETRICAL.

THE BRAHMAPUTRA SERIES, MERIDIAN 90°.

(27.) This important meridional chain of triangles lies wholly between the Calcutta and the Assam Longitudinal Series. It was commenced at the south end, in 1867-68, and was completed during the present year, having been executed throughout as a chain of successive polygonal figures. Lying almost wholly in alluvial plains, lofty towers have had to be erected as stations of observation, in nearly every instance, and almost all the lines between these towers have had to

be cleared of trees and jungle; thus though the labor entailed has been very considerable the progress has been comparatively slow, averaging 30½ miles per annum, the entire length of the series being 220 miles.

(28.) At the commencement of the present year a gap of 54 miles remained to be completed, in order to connect the principal triangulation from the south with that to the north; all the intermediate stations had however been selected and built, and the lines between them had been cleared, and thus during the present year there was little to be done in the way of preliminaries before the commencement of the principal triangulation; at a few of the stations bamboo scaffoldings had to be erected for the support of the observatory tent, and a few lines, in which jungle had grown up since they were first cut, had to be re-cleared.

PERSONNEL.

Captain Carter, Officiating Deputy Supdt. 2nd grade.
Mr. L. H. Clarke, Surveyor 2nd grade
„ Collins, Asst. Surveyor 4th grade.

(29.) Captain Carter took the field at an early date, being anxious to complete the triangulation before the month of March, when the villagers usually begin to burn the grass and bamboo jungles, and the atmosphere is so pervaded with smoke and haze that all distant objects are altogether shut out from view for weeks together, until the periodic rains commence to fall and clear the atmosphere. Fortunately he was successful in finishing the requisite observations by the 6th March, but he found the field season a particularly trying one, for though it was short he was all the while working against time.

(30.) Captain Carter deputed Mr. Clarke to execute secondary triangulations for the purpose of fixing the positions of points of importance in the vicinity of the series which could not be seen from the principal stations. Mr. Clarke was more particularly instructed to fix as many as possible of the stations of the Revenue Survey which had been completed in the Rungpore and adjoining districts before the triangulation was commenced; but no station marks were met with, presumably because the reasonable procedure of constructing permanent pillars at the points of junction of three or more villages—which prevails in the North-West Provinces and the Punjab, and furnishes a certain number of permanent marks for future reference which are invariably incorporated among the stations of the Revenue Survey—has only commended itself to the approbation of the Bengal Government very recently, and at the time when the surveys of Rungpore and the adjoining districts were being carried on, no such pillars were erected; thus the only means of making a connection between the trigonometrical and the revenue operations was by fixing the positions of all the temples which were met with, and also of the banyan trees under which the villagers hold their markets. On entering the Goálpára District 25 permanent marks were fixed by Mr. Clarke, and these should be of much use to the Revenue Surveyors who are now employed in that district.

(31.) The connection of the triangulation of the Brahmaputra with that of the Assam Series has completed a chain of triangles—between the Calcutta and the Sonakhoda base lines—of which the length is 420 miles, and which forms with the Calcutta Meridional Series a circuit of 660 miles. The errors at the close of the circuit were only 0″·18 in latitude and 0″·23 in longitude, and may be considered immaterial. On the other hand the linear error generated between the base lines was as much as 4·4 inches per mile, which is larger than any linear error hitherto met with at the close of either of the principal chains of triangles of this Survey; it is probably due to the circumstance that the triangulation was wholly carried over plains which were covered with jungle and tropical vegetation, and consequently the necessity arose for opening out lines in every instance, in order to secure mutual visibility without incurring the expense of raising the stations to a great elevation; there is always a tendency to lateral refraction in rays which graze the surface of the ground or the sides of glades, and this may effect the observations very sensibly. But errors arising from lateral refraction tend to cancel each other in the long run, and the small errors at the close of the circuit indicate that in the present instance this has probably happened.

NO. IV.—TRIGONOMETRICAL.

THE JODHPUR SERIES, MERIDIAN 72¾°.

PERSONNEL.

Capt. J. Hill, R.E., Offg. Deputy Superintendent, 3rd grade.
Mr. W. C. Price, Asst. Surveyor, 1st grade.
Mr. C. P. Torrens, Asst. Surveyor 3rd grade.
Mr. W. Oldham, Asst. Surveyor 3rd grade.

(32.) This chain of triangles—which was commenced last year at a side on the north flank of the Karáchi (Kurrachee) Longitudinal Series, by Lieutenant M. W. Rogers—has this year been advanced a considerable distance northwards, by Lieutenant (now Captain) Hill, who succeeded Lieutenant Rogers on his departure to Europe on furlough.

(33.) The operations of the present year lay in the desert of Marwar and Jesalmer, through the tract which is called "the region of death," in Greenough's General Sketch of the Physical and Geological features of British India; happily it was this year found to be undeserving of so dire an epithet, for the survey party enjoyed excellent health, on the whole. The region is however much dreaded by the people of the surrounding more favored districts, probably, as Captain Hill reports, "on ac- "count of its desolate appearance, the frequency of its famines, and the distress "and disease that are generally prevalent among the poorest classes of its inhabi- "tants, owing to the miserable food and unwholesome water on which they are "compelled to subsist".

(34.) The desert is covered with sand hills "which are generally flat "topped, low, and of about equal altitude, so that the advantages of a hilly "country are lost, and short sides are unavoidable." On the other hand however the absence of vegetation relieves the surveyor of the necessity of building towerstations and clearing the lines between them, which is a great advantage, and enables the operations to be carried on far more rapidly and economically than would be possible in Eastern Bengal, in Assam or in Burma. Special arrangements have to be made to provide the surveyors with food and wholesome water, in this region where neither the one nor the other is procurable; but camels are plentiful and readily obtained, and thus, with a little forethought and at a slight expense, there need be no risk of failure in the supply of the necessaries of life. Occasionally observations are delayed when the atmosphere is pervaded with dust and sand, but not to any thing like the extent which happens in the forest and jungle tracts of India, when the grasses are fired and a thick pall of smoke and haze obscures the atmosphere, sometimes for weeks together.

(35.) The out-turn of the field season's work is very good and creditable to Captain Hill and his assistants. The principal triangulation was carried a distance of 90 miles along the meridian, by a series of consecutive polygonal figures which embrace an area of 1,552 square miles. An astronomical azimuth of verification was measured at one of the principal stations. The preliminary operations for the selection of the sites of the stations were carried over a distance of 102 miles and have been kept well ahead of the final triangulation. And secondary chains of triangles have been extended from the main series, in the course of which the positions of upwards of 80 points, and the heights of 29 of these points, have been fixed.

(36.) When the net work system of triangulation, which had been adopted by Major Lambton for the operations in southern India, was superseded by the method—introduced by Colonel Everest—of meridional and longitudinal chains of triangles, it was intended that the meridional chains should be placed at about 1° apart, and tied together by longitudinal chains at convenient intervals; and this intention was carried out over the entire extent of country lying to the north of the parallel of Calcutta and between the meridians of 74° and 89°. Of late years however it has been deemed unnecessary to execute so large an amount of principal triangulation, and consequently the intervals between the main meridional chains have been made about twice as great as formerly; thus between the

Indus Series and the Gurhágarh there will be only two principal series—the Jodhpúr and another on the meridian of 70°—instead of five, the number originally contemplated. But this reduction in the amount of the principal requires an increase in that of the secondary triangulation, otherwise a sufficient number of fixed points of reference will not be provided for the use of topographical and fiscal surveyors and the public generally. Arrangements are therefore being made to run longitudinal chains of secondary triangles, at intervals of about 1° apart, from the Indus to the Jodhpúr Series; these will be carried on rapidly with light and portable instruments, as soon as the stations have been selected and permanent marks built at them for future reference.

NO. V.—TRIGONOMETRICAL.

THE EASTERN FRONTIER SERIES, IN BURMA.

(37.) This chain of triangles emanated from the Assam Longitudinal Series, near Gowhatti, in the year 1861-62; in the following years it was carried through the Kasia and Tipperah Hills, and then down the east coast of the Bay of Bengal, through the districts of Chittagong, Akyab and Arracan, to the vicinity of Toangoup and Sandoway; it was then diverted eastwards, into British Burma, over the range of hills which intervenes between Arracan and Prome; and by the year 1869-70 the principal triangulation had been completed to a short distance beyond Prome, and stations had been selected in advance across the northern portions of the British districts and down the eastern frontier, to the vicinity of Moulmein. The operations were then suddenly arrested, in consequence of the financial embarrasments of the Government of India, which necessitated large reductions of expenditure in all directions. The expenses of the triangulation—as well as of all operations requiring a large amount of local labour, though only for a short time—are vastly greater in Burma than in any part of India proper; as the country is very thinly populated, the wages of common daily laborers are increased fourfold, and those of the regular native establishments have to be more than doubled; the country is covered with dense forests, up to the very tops of the hills, and consequently extensive clearances have to be made and long lines cut, and that frequently in uninhabited or very sparsely inhabited localities, to which laborers have to be brought from great distances; local allowances are necessarily granted to all the surveyors; and all this raises what may be called the contingent expenditure, or the excess above the normal pay of the surveyors, to about three times what ordinarily prevails in India proper. Thus when reductions of expenditure were called for in 1870, the series in Burma was naturally selected as the one to be stopped, for thus the largest savings which could be made with the least injury to private individuals were effected.

(38.) This year I was directed by the Government not only to resume the triangulation in Burma but to push it on with all possible vigour, though without any increase of expenditure over the amount provided in the Budget. Happily the services of Messrs. W. C. Rossenrode and H. Beverley, who had been carrying on the triangulation when it was suspended, were available for its resumption, without detriment to the operations in other quarters; for the Bilaspúr Meridional Series, on which these gentlemen had latterly been employed, was completed last year, by the junction of its two sections, one of which had been brought up from the south by Mr. Rossenrode and his party, and the other carried down from the north by the party under Mr. Keelan. In order to meet the expenses which would now be caused, Mr. Keelan was transferred to do duty at Head Quarters, his party was broken up, and the funds which had been provided for its employment elsewhere were placed at Mr. Rossenrode's disposal.

PERSONNEL.

W. C. Rossenrode, Esq., Deputy Superintendent 3rd grade.
Mr. H. Beverley, Surveyor 1st grade.
„ J. W. Mitchell, „ 4th „
„ J. C. Clancey, Asst. Surveyor 4th grade.

(39.) The first thing Mr. Rossenrode had to do was to induce a sufficient number of the trained native subordinates to re-engage for service in Burma, and to fill the places of the large number of men who were unwilling to commence a life of banishment from their native country. These difficulties surmounted, and a party formed which promised to be efficient, Mr. Rossenrode embarked with it on board a steamer at Calcutta, and reached Rangoon on the 7th November.

(40.) Meanwhile arrangements had been made to obtain a supply of elephants for the party, as without the aid of these serviceable animals the operations could not be carried on. Ten were procured at Moulmein, under the orders of the Chief Commissioner, and they arrived at Rangoon a few days after the party; they were found to be very fine animals but untrained and shy, and they had never carried loads; they were immediately put under training by the mahouts whom Mr. Rossenrode had brought with him for the purpose from Bengal. But it was long before they could be made use of, and in the interim a few elephants were obtained on loan from the Commissariat Department, and then Mr. Rossenrode commenced his march northwards, and on the 4th of December reached one of the stations in the plains of the Henzada District, down to which the principal triangulation had been brought in previous years.

(41.) I may here observe that in the original design of the triangulation provision was made for the measurement of a verificatory base-line in the plains of the Henzada District, on the same parallel of latitude as the base-lines already measured at Bider and Vizagapatam; a suitable line was selected and cleared, and towers were built at its extremities as stations of the principal triangulation. But this is almost the only instance in which the principal triangles have been brought down from the hills into the plains, for the plains are invariably covered with luxuriant vegetation and frequently with dense forests, and consequently high towers have to be built and heavy line-clearances made to render the stations mutually visible; and the less there is of this sort of thing the better, everywhere, and in Burma more particularly.

(42.) Mr. Rossenrode commenced operations by clearing the lines of the jungle that had grown up on them during the four years which had elapsed since they were first cut. During the months of January and February he took the necessary observations at three stations on the plains and at four hill stations. On the 10th March he reached the hill station of Kaneingdong, which is about 50 miles north of Pegu. The sides of the triangles which converge on this station are of various lengths, ranging from 22 to 43 miles, longer sides than usual having been introduced in order to cross over the Sittang valley by a single span, and thus avoid bringing the operations down into a flat and densely wooded country. Unfortunately the burning of the jungles had commenced, and the thick haze and smoke shut out all view of the surrounding stations; even hills which were only five miles distant were entirely obscured. For nearly two months Mr. Rossenrode had to remain at the station, watching 'by night and day' for glimpses of the lamps and heliotropes, but in vain; eventually, in the first week of May, a shower of rain fell and cleared the atmosphere, after which the observations were speedily completed. Mr. Rossenrode then proceded to his next station, Myayabengkyo, where, on the 11th May, the monsoon set in with such violence that during the breaks he was only able to complete the angles to the back stations, which were comparatively near and low; the forward stations were far off, and one of them was so elevated that it was constantly capped with clouds or enveloped in mist, and so the signals could not be observed. He had therefore to close work and proceed to his recess quarters at Moulmein. The march was performed "with "much inconvenience and difficulty, owing to the whole country being submerged, "the depth of water varying from one to four feet, throughout each stage".

(43.) What has been stated will suffice to show the great difficulties of carrying on the triangulation in Burma. When the stations are situated in the plains, at comparatively short distances apart, the progress of the work is much less dependent on the condition of the atmosphere than when they are on hills far apart from each other, and the final observations can be completed with great-

er rapidity; but, on the other hand, the preliminary operations of selecting sites, building towers and clearing lines, are very laborious and expensive and cause great delay; thus, as a matter of economy of time and money, the plains are never entered when they can be avoided. Even the hills present many difficulties, as they are always covered with forest and are frequently flat topped and do not afford a commanding view all round from a single point; thus on one occasion it cost even so skilful and practised an officer as Mr. H. Beverley three weeks of hard labor to find a suitable site for a station, on the low and undulating ranges to the south of Shoaygheen.

(44.) The out-turn of work comprises a double polygon, covering an area of 1,294 square miles, by which the principal triangulation has been advanced a direct distant of 50 miles. The preliminary operations were carried over a distance of 112 miles, in which the stations have all been selected and built in readiness for the principal triangulation of the next year. Stations have also been selected for a secondary chain of triangles, to connect the important towns of Rangoon and Pegu. Considering all the difficulties with which Mr. Rossenrode had to contend in this first year of the resumption of operations in Burma, that he had to form a new native establishment for the work, that much of the best time of the year was necessarily devoted to preliminary arrangements, and that the operations were seriously retarded by causes which were altogether beyond his controul, I think that he is entitled to much credit for what has been done; his arrangements have been very judicious and satisfactory, and I believe he has done his best to carry out my instructions to economize the funds placed at his disposal for the prosecution of the operations.

NO. VI.

SPIRIT LEVELLING OPERATIONS IN THE MADRAS PRESIDENCY.

(45.) A suspension of the astronomical and geodetic operations in the Madras Presidency, which are described in Sections X and XI of my Report for 1872-73, having been rendered necessary because of Captain Herschel's departure to Europe, Lieutenant Harman, R.E. was placed in charge of Captain Herschel's party, and employed in in spirit levelling. His operations were carried on in a manner precisely similar to those in Sind, the Punjab, the North-West Provinces and Bengal, which have been briefly described in previous reports, and in full detail in the introduction to the *Tables of Heights in Sind &c.* Calcutta 1863, and also in Volume XXXIII of the *Memoirs of the Royal Astronomical Society;* and their object was the same, *viz.*, to connect together and reduce to a common datum the several lines and systems of levels executed for Railways, Canals and other Public Works, and to check the values of height of the principal stations of this Survey which have been determined by the trigonometrical method.

PERSONNEL.

Lieut. H. J. Harman, R.E., Offg. Assit. Supdt. 1st Grade.

Mr. O. V. Norris, Asst. Surveyor 2nd Grade.

(46.) This is the first year that I have been able to employ a party, in the Madras Presidency, solely on levelling operations; arrangements had been made to form a special party for that Presidency in 1869, but they fell through in consequence of financial difficulties; and thus hitherto the work of this nature which has been done there, by this Survey, consists of short lines of levels, to connect the Cape Comorin base-line with the tidal station at Tuticorin, and the Bangalore base with the railway levels from the sea at Madras.

(47.) The several systems of levels for the Public Works in the Madras Presidency are so numerous that it was difficult to decide where to commence our operations. Major Branfill had, at my request, obtained from the officers of that

Department a Skeleton Map of Southern India, showing the lines of levels which had been taken by the several Railway Companies and the Canal Officers, each of which was referred to a separate datum. It was necessary to refer them all in turn to the mean sea level, as deduced at stations where systematic tidal observations, continued over a long period, had been or would be taken. There was then, and still is, only one such station, Tuticorin; but the establishment of others, at various points on the east and west coasts, was contemplated, and the first of these would probably be at Karwar, the well known port on the west coast. A line from Tuticorin would not have been immediately useful for combining the several existing systems of levels; consequently Lieutenant Harman decided on commencing operations at Gúti (Gooty) and working westwards through Bellary, Dharwar and North Kanara to the port of Karwar.

(48.) This line was completed very satisfactorily, and is 304 miles in length. One of the sections traverses the Arabail Ghát, and was found to be "almost intolerably hilly for the work," the sum of the rises and falls aggregating 11,251 feet. Two trigonometrical stations, and thirteen points on the railway and irrigation lines were connected; sixteen bench-marks were laid down, and upwards of three hundred other points were fixed for future reference.

(49.) A site was selected and marked for the future tidal station at Karwar. Every effort was made to ascertain whether the tidal observations which had been taken several years previously at this post, by officers of the Indian Navy, had been referred to some permanent point of reference on the coast; but none such could be found, or Lieutenant Harman would have connected it with his line of levels. Under the circumstances it was necessary for him to make an approximate determination of the mean sea level by a few days observations of the tides; these, when reduced to the "mean of the year" with the aid of the local tide tables, will furnish a very fair preliminary determination of the mean sea, to serve for immediate requirements, pending the completion of the systematic observations to be taken hereafter with a self-registering tide-gauge.

(50.) Lieutenant Harman has labored with great energy and self devotion during this his first year of independent employment. He was unfortunately unable to complete the bringing up of his field books and the preparation of the results for publication, for before he could do so I was obliged to send him away, with scant notice, to a part of India very distant from the scene of his operations. He is now conducting the Assam Valley Triangulation, with orders to join the Survey Party attached to the military expedition against the tribe of Duflas; this tribe occupies a tract of hills to the north of the valley, which has hitherto appeared on the maps as a *terra incognita*, but which I trust will soon be thoroughly explored and mapped.

NO. VII.—TOPOGRAPHICAL.

THE SURVEY OF KATTYWAR.

(51.) The operations of this important topographical survey have been carried on during the present year under the executive superintendence of Captain Pullan. Good progress has been made, both in the field work and the mapping, and the completion of the survey of the entire Province of Kattywar, within the next five years, may be confidently looked forward to.

PERSONNEL.
Capt. A. Pullan, S.C., Offg. Deputy Superintendent 3rd Grade.
J. McGill, Esq., Assistant Supd. 2nd Grade.
Mr. F. Bell, Surveyor 3rd Grade.
„ J. Wood, „ 4th „
„ N. C. Gwynne, Asst. Surveyor 1st Grade.
Mr. E. Wyatt, Assist. Sur. 2nd Grade.
„ W. A. Fielding, „ 3rd „
„ H. Corkery „ 4th „
Visaji Ragonath and 12 Native Surveyors and Apprentices.

(52.) The final topographical operations embraced an area of 2,201 square miles, which comprises portions of the Districts of Hallar, Machu Kanta and Jhalawar and of the principal Native States—Nawanagar, Morbi, Rajkot, Wakanir and Gondal—which are included in those Districts.

The entire area was surveyed on the scale of 2 inches to the mile, by the usual method of plane tabling on a trigonometrical basis, but with the addition of a large amount—1,235 linear miles—of traversing, to lay down the boundaries of the talukas and furnish checks on the operations of the plane tablers. A survey of the town and cantonments of Rajkot was made on the scale of 12 inches to the mile, in doing which all the principal roads were traversed with chain and theodolite and stone bench-marks were fixed at a number of important points on the traverses, for future reference.

(53.) The triangulation executed in advance, for the topographical operations of next year, covers are area of 2,174 square miles, in which 578 points have been fixed, and the heights of 309 of these points have been determined.

(54.) The mapping comprises 20 sections, each 32 × 17 inches, on the 2-inch scale, drawn for reproduction on full scale and also for reduction by photography to the 1-inch scale, and a degree sheet on the ½-inch scale, drawn for reduction by photography to the ¼-inch scale, for incorporation into the Indian Atlas;—also a map, 44 × 35 inches, of the Rajkot Town and Cantonments, on the 12-inch scale. Owing to an unfortunate oversight which has been made in the mapping, the breadth of the talúka boundary lines has been very unnecessarily increased on one of the 2-inch maps, the appearance of which has been much deteriorated in consequence.

(55.) The delays attendant on the demarcation of the boundaries of the Native States, prior to survey, have in some instances been so great that the survey of the country had to be carried on without waiting for the demarcation of the boundaries, the directions of which could therefore only be shown approximately on the maps; Captain Pullan reports that most of these detached bits of boundary have now been definitely settled and marked out, and that they will be surveyed next year.

(56.) The Kattywar Survey Party has been much weakened this year by the deaths of two of the assistants, and the loss of a third who has become lunatic. Mr. J. Wood died suddenly, and most sadly, shortly after his return to recess quarters in May; he had served in the Department for nearly fourteen years, was very intelligent, and had always worked willingly and well, and given every satisfaction to each of the officers under whom he had been employed. Mr. E. Wyatt had been compelled by ill health to take leave of absence at the close of the field season; he was never able to rejoin, and died in the following November; he had served for nine years, and had become a very skilful draftsman, as well as a useful surveyor, and his loss is much regretted.

NO. VIII.—TOPOGRAPHICAL.

THE SURVEY OF GUZERAT.

(57.) In section VIII of my report for 1872-73 I have shown that, from the very commencement of our operations in Guzerat, the importance of endeavoring to effect a combination of our work with that of the Revenue Surveyors who had preceded us in that Province, with a view to utilizing their work to the utmost possible extent, had been fully recognized; I indicated the attempts which had been made

PERSONNEL.

Major C. T. Haig, R.E., Deputy Supdt. 2nd Grade.
Lieut. J. E. Gibbs, R.E., Assistant Supdt. 2nd Grade.
Mr. J. Peyton, Surveyor 1st Grade. (During the recess only)
" A. D'Souza, Surveyor 2nd "
" A. D. L. Christie, Surveyor 4th Grade.
Mr. C. H. McA'Fee, Asst. Surveyor 1st Grade. (During a portion of the field season only)
Mr. E. J. Connor, Asst. Surveyor 1st Grade.
Mr. J. Hickie, Assistant Surveyor 2nd Grade.
Mr. G. D. Cusson, Asst. Surveyor 3rd Grade.
Mr. A. Bryson, Asst. Surveyor 3rd Grade.
Mr. G. T. Hall, Asst. Surveyor 4th Grade.
11 Native Surveyors and Apprentices.

REVENUE SURVEYORS.

Mr. T. A. LeMesurier.
5 Native Surveyors.

to do so, and showed that they had met with such varying results that while some officers pronounced the combination to be impossible, others thought that it might be effected, and with very great advantage as regards the general value and utility of the maps.

(58.) I myself had from the first been inclined to take the more favorable view, on the general grounds that it appeared impossible that the myriads of measures which had been made for the purpose of defining the areas of all landed properties, down to the minutest fields, and which had been plotted together so as to form village maps on the large scales of 8 inches and 16 inches to the mile, could not be utilized to some extent in the course of the execution of a professional survey of the country.

(59.) Moreover utilization appeared to me to be most desirable, in that, if feasible, it would tend to improve the character of the professional survey. That survey was about to be undertaken by an establishment which had been formed on the old and long standing scale of establishments for the production of rapid preliminary maps, and consequently contained a much larger proportion of the European than of the Native element; for the object to be accomplished was the attainment of a rapid but only fairly accurate survey of the country; the method to be adopted was that of plane tabling, and each plane tabler was expected to turn out a much larger area in a given time than could possibly be obtained, of minute and close survey, in the time allowed; thus an out-turn of about 100 square miles *per mensem*, during each month that the plane tabler is actually on the ground under survey, is even still considered a fair average out-turn for the scale of 1 inch = 1 mile, and formerly a much larger out-turn was expected. But the country of Guzerat is a rich and fertile plain, covered with trees and fences and habitations, and consequently very ill suited for a rapid survey by the method of plane tabling. Thus it appeared to me to be most probable that if the professional surveyors did not utilize the facts of measurement which they might obtain from the revenue surveyors, either they would have to do over again, at great expense, a large portion of the work of minute measurement which had already been done at great expense, or their maps would be found wanting in accuracy of detail in those parts of the country which are most densely inhabited and most rich and valuable. In the latter case the expectations which would naturally be formed of a professional survey of the "Garden of Western India", executed at the present time and upwards of a century after the country had become a British possession, might be grievously disappointed.

(60.) For the last two years the survey has been under the executive superintendence of Major Haig, who has shared my belief in the practicability of utilizing the fiscal measurements, and has labored earnestly and patiently in working out the best method of doing it. He soon found that a certain amount of co-operation on the part of the Revenue Surveyors was essential to success; this was reported to the Bombay Government, who readily acceded to the proposals submitted for sanction, and sent a small but sufficient party of native surveyors—at first under Mr. A. Dalzell and afterwards under Mr. T. A. LeMesurier—to assist Major Haig; this they were to do by giving him full details of the fiscal measurements, and indicating the positions of the principal pillars and marks of reference, the fixing of which by Major Haig's surveyors was a necessary preliminary to the incorporation of the fiscal details into their maps.

(61.) The Survey of Guzerat had originally been commenced on the same scale as that of the adjoining Province of Kattywar, namely 2 inches to the mile, or $\frac{1}{31680}$; but it was clear from the out-set that this scale, though well suited for the portions of Guzerat which are under Native States, and are not directly administered by the British Government, and have not been brought under fiscal survey—as is the case with by far the greater portion of Kattywar—might not be sufficiently large for the districts which are directly under British administration and have been fiscally surveyed. What scale should be adopted was a matter on which no conclusions could be arrived at, until the problem of the practicability of utilizing the fiscal measurements at all, and if so to what extent, had been

satisfactorily solved. In my last annual report I had to acknowledge that, owing to circumstances which are there fully explained, it was still premature to form any positive conclusions on the subject. I am now in a position to state that the scale of 4 inches to the mile may be adopted with advantage, and that Major Haig has succeeded in executing several excellent maps on that scale.

(62.) The reason why an equal measure of success was not attained previously is that, originally, a comparatively small number of the fiscal marks had been fixed, and an attempt had been made to join entire village maps together by their peripheries; the maps however are often of considerable size, and it so happens—from the system of operation in the field measurements—that the peripheris are the parts where there is greatest accumulation of error; thus when contiguous maps were juxtaposed, large discrepancies were occasionally met with, more particularly on lines of considerable length, and they were found to be unmanageable. But Major Haig has ascertained that, by fixing a sufficient number of the fiscal marks to enable the village maps to be cut up into triangles with sides not exceeding three quarters of a mile, the details can be fitted on his maps without any sensible inaccuracy. The greater number of the marks are fixed by the triangulation and the traverses, and the remainder by the plane tablers, who are required to pick up all obligatory points which had not been fixed by the surveyors preceding them.

(63.) The village maps show with accuracy all the walls, fences and hedges which form the boundaries between contiguous fields and properties in enclosed tracts of country, and the narrow strips of uncultivated land which form the boundaries in open country; but, as is well known, they do not give topographical features at all, nor do they give the roads and water courses which are exterior to the cultivated and cultivable fields with any attempt at accuracy. The system of operation which Major Haig introduced last year was to have the fitting in of the details which are given in the village maps effected on the ground, by the plane table surveyors, *pari passu* with the survey of the topographical details. This year however he has found it preferable to restrict the plane tablers to the survey of the topographical details, and to the fixing of such additionrs points as may be necessary to enable the details of the village maps to be subsequently plotted on their tables, under his immediate supervision.

(64.) With the object of obtaining a fair practical test on his system of combination, he carried on operations in two parts of the district, at some distance from each other; in the Ahmedabad Collectorate, where the Revenue Survey operations had been carried out nearly a quarter of a century ago, and in the Surat District, where they had been done recently. The old work was known to have been much more roughly executed than the modern, but the errors of the sections into which it is now subdivided, as already explained, were found to be easily manageable; on the other hand in the new work the errors almost entirely disappeared, and Major Haig is of opinion that the new work is suitable for reproduction even on the 8-inch scale, should this be required.

(65.) If the whole of Guzerat consisted of lands which have been fiscally surveyed, I should have no hesitation in concluding that the whole ought to be surveyed on the 4-inch scale, as Major Haig has been doing, whereby a series of maps would be available for this neglected portion of India, on the same scale as those which have long ago been constructed for the British Districts in Bengal, the North-West Provinces, the Punjab, and Oudh. But the fiscal operations do not cover more than a third of the area of the province. The lands subject to the British Government are held under three kinds of tenure, known as Khálsa, Tálukdári, and Inámi; in the Khálsa villages every field has been surveyed fiscally, for the owner of each field pays his rent directly to the Government; in the Tálukdári villages a Tálukdár pays the rent for the whole village, and consequently the fiscal maps usually give only the boundary lines and the roads, and occasionally a little partition into fields; while of the Inámi villages generally no maps are forthcoming. Thus the value of the fiscal work for topographical purposes is almost solely restricted to the Khálsa lands. Consequently it is of these

lands alone, with as much of the others as are interlaced with them, that 4-inch topographical maps should be made; the remaining portions of the province, comprising the British Tálukdári and Inámi villages, the villages belonging to Native States and the Dáng Forests, should be surveyed on the 2-inch scale, as is being done in Kattywar.

(66.) The triangulation of the field season under review embraces an area of 1,650 square miles, in which the positions and heights of 237 points, and the positions (without heights) of 337 points have been fixed, in advance, for the topographical operations. And this triangulation has been supplemented by 848 linear miles of traverses, furnishing a large number of traverse stations, of 1,268 of which the co-ordinates have been computed.

(67.) The area embraced by the topography is about 690 square miles, which is a smaller out-turn than was accomplished in former years, when the scale employed was only half as great; but being the first season of work on the 4-inch scale, and of successful combination with the fiscal materials, I consider it very satisfactory and creditable to Major Haig and his assistants. Major Haig expects that with a little more practice, and a slight increase to his grant for contingent expenditure, the party will be able to turn out nearly as much work annually on the 4-inch scale, as could be accomplished, in those portions of the district which have not been operated in by the Revenue Surveys, on the 2-inch scale.

(68.) Eight maps on the 4-inch scale, each measuring 32 inches by 17, and embracing 7′ 30″ in longitude and 3′ 45″ in latitude, have been completed and sent in to this office, and are now being photozincographed. They show all the walls, fences and other divisions between the fields; they also show the 'numbers' by which the fields are registered in the fiscal records, and which have thus come to be popularly used, by the owners and villagers and the public generally, as the names of the fields. They give all the details which are given on the fiscal map, and all the topographical information which is required to supplement those details. They cannot but be most useful to the local officials in the administration of the country, to engineers employed in laying out lines of roads, canals, and railroads, and more particularly for local irrigation works, when it is a matter of great importance to have a map showing the fields which are brought under irrigation, and the owners of which have to be taxed in proportion to the benefits they receive. The only regret I have felt in looking at these maps is that the excellent fiscal work which has been done by the Revenue Surveyors was restricted to the Khálsa lands, instead of being carried over the entire province. Thus while some portions of the maps are elaborately detailed, other parts—as for instance where a Tálukdári or Inámi village comes in among a cluster of Khálsa villages—are comparatively meagre and deficient in detail. This is somewhat detractive from the artistic appearance of the maps; but I am content to waive appearances, and be satisfied with the practical gain secured by utilizing the work which was done before we came into the field, and which we have found ready to our hands; I would not advocate the securing of uniformity and superior artistic finish, either by assimilating the Tálukdári and Inámi to the Khálsa villages, which would cause much additional expense, or by suppressing the results of the fiscal surveys in the Khálsa villages, which would be to abandon all the fruits of the laborious and expensive operations carried out by our predecessors.

(69.) Major Haig makes prominent mention of the services of Lieutenant J. E. Gibbs R.E., who was employed in triangulating a portion of the Dáng Forests, and whose interesting notes on the manners and customs of the inhabitants, &c., will be found at page 32—$_a$ of the appendix,—of Mr. T. A. LeMesurier, of the Bombay Revenue Department, whose intelligent and cordial co-operation has much contributed to the success which has been attained in combining the fiscal with the topographical details;—and of Mr. A. D'Souza, who was of great assistance in training the native surveyors and supervising their operations.

NO. IX.—TOPOGRAPHICAL.

THE SURVEYS IN DEHRA DUN.

(70.) The Himalayan Mountain ranges may, for geographical purposes, be broadly divided into two portions, one lying to the east the other to the west of meridian 81°. The eastern portion includes the Nepaulese territories, Sikkim, Bhútan, and the ranges to the north of the Assam Valley which are occupied by independent hill tribes; in this portion most of the prominent peaks have long since been 'fixed' by the operations of this Survey, but only a very small area has been regularly surveyed, and under existing political conditions any considerable extension of survey operations is impossible. The western portion, on the other hand, has long been freely accessible to Europeans, and regular surveys of the entire area included between the plains of Hindostan on the south, the frontiers of Eastern Turkestan and China on the north, and the tracts occupied by independent hill tribes in the Valley of the Indus on the west, have now been all but completed. These surveys have been executed on various scales, and at various times, by members of this Department.

(71.) First the districts of Kangra, Lahaol and Spiti, and the Native States of Chamba, Tíri and Garhwál, which embracing an area of 26,700 square miles, were surveyed during the years 1849-54; the maps were drawn in the field on the scale of ½ inch = 1 mile, but evidently with a view to publication on the ¼-inch scale of the Atlas Sheets and with the object of exhibiting the general geographical rather than the exact topographical features, for the average area turned out every field season by each person employed exceeded a thousand square miles; the operations were carried on under the direction of the late Surveyor General and Superintendent of the Trigonometrical Survey, Sir Andrew Waugh, and furnished a series of valuable preliminary maps of regions, including three British Districts, which had hitherto been unsurveyed. Then the survey of the territories of the Maharajah of Kashmir was commenced, and an area of about 21,800 square miles was completed in Kashmir and Jammú on the ½-inch scale, but with much more topographical detail than had been given in the preceding survey; and after this the operations were extended over the remainder of the Maharajah's territories, but on the smaller scale of ¼ inch to the mile, which was adopted for an area of about 52,000 square miles, comprising the whole of Ladakh, Little Thibet and the regions up to the northern boundary line, and a portion of Chinese Thibet beyond; these operations were carried on during the years 1854-64, and were initiated by Sir Andrew Waugh and carried out by Major Montgomerie, mostly under his directions. Lastly a survey of the British District of Kumaun and Garhwál was commenced in 1865, on the scale of 1 inch = 1 mile, and it is now nearly completed; the western frontiers of Nepaul have been reached and surveyed to the furthest points visible from our own side of the frontier; the area completed amounts to 9,520 square miles within, and 270 outside, the districts; the area remaining may be roughly estimated as amounting to 3,200 square miles; it is situated for the most part in the higher ranges and regions of perpetual snow, which lie to the north towards the frontier of Chinese Thibet, and much of it may be surveyed on a smaller scale.

(72.) Thus when, in May 1873, I replied to a call from the Government to sketch out a programme of operations for each of the Trigonometrical Survey parties for the next five years, I suggested that, as it would not be possible for us to operate in the interior of Nepaul nor in any portion of the Eastern Himalayas, the Kumaun and Garhwál party should be employed in re-surveying the districts of Jaunsár-Báwar, Kangra, Kúlú and Spiti, which are under the direct administration of the British Government, making a detailed survey on a scale suitable for local requirements, to supersede the original small scale geographical survey. My proposals were approved of by the Government, and by Her Majesty's Secretary of State for India; and the operations will be commenced as soon as is practicable.

(73.) They will however necessitate some important modifications in the method of survey hitherto employed, and in the personnel of the surveyors. Until the year 1865 the object in view was to obtain rapid and skilfully generalized sketches of the principal topographical features of the country, and therefore none but European surveyors were employed. The surveys subsequent to that year were executed on a larger scale, and are very much more minute and elaborate; so much so that it has been necessary to publish the results in two sets of maps, one shewing all the hills and general topographical features and the principal villages, the other in a skeleton form, omitting all hill shading, but showing the water courses and the whole of the villages and hamlets and various details which could not be introduced into the shaded maps;—these surveys have likewise been done by a purely European agency. But it has been shewn to be clearly advantageous to employ native agency also to a certain extent, and to introduce as many native surveyors into the party as can be efficiently supervised, in order that the cost of the operations may be reduced as much as may be practicable without impairing the value of the results. Steps had therefore to be taken to train a certain number of natives for the future operations.

(74.) An excellent opportunity for so doing occurred during the present year. When Captain Bailey, the Superintendent of the newly formed Department of Forest Surveys, was temporarily affiliated with this Department, for the reasons already mentioned in para (11.) of this report, it was at first intended that he should make a survey of the whole of the Dehra Dún District, a re-survey of which has long been much wanted, owing to the great increase of cultivation and the formation of extensive tea-plantations since Major Brown's survey in 1840. As the forest tracts are much interlaced with the cultivated tracts and the tea-plantations, a survey of both was necessary to complete the map of the District; and as the area of the former considerably exceeds that of the latter, Captain Bailey might have surveyed both, without his own operations being very materially retarded; and this was at first intended, for it would have afforded an admirable opportunity for imparting the requisite training to his establishment, to fit them for their work in other parts of India. After a few months however the calls on Captain Bailey from all quarters became very numerous, so that it seemed uncertain whether he could even be permitted to remain to complete the forest tracts, and quite certain that he ought not to undertake anything exterior to them. Consequently I directed Captain Thuillier to withdraw a portion of his assistants from the Survey of Kumaun and Garhwál and employ them in the non-forest tracts of the Dehra Dún, and also to commence training a body of native surveyors, to be employed on measurements of boundary lines and road traverses, and in various other matters for which an expensive European agency is not desirable.

(75.) Commencing operations in the month of November, Captain Thuillier was able to avail himself of the services of almost the whole of the Kumaon and Garhwál party—the exceptions being Mr. Peyton who was employed in mapping, and Mr. Low who was still in the higher ranges, working up the valley of the Gori towards the passes above Milam—for it would have been useless at that time of the year, with the winter fast setting in, to send men into the unsurveyed portions of Kumaon and Garhwál, which were all at such great elevations as to be only accessible during the comparatively warm months immediately preceding and following the summer monsoon. Thus Mr. Ryall and two assistants were employed in the Dún until the end of the month of March, when they proceeded to resume the operations in the higher ranges, as will be described hereafter.

PERSONNEL.

of the Kumaon and Garhwál Party.

Captain H. R. Thuillier, R.E., Offig. Depy. Supdt. 1st Grade.
E. C. Ryall Esq. Offig. Asst. Supdt. 2nd Grade.
Lieut. St. G. Gore, R.E. Offig. Assist. Supdt. 2nd Grade.
Mr. J. Peyton, Surveyor 1st Grade.
" J. Low, " 3rd "
" L. Pocock, Asst. Sur. 1st "
" J. Macdougall, Asst. Surveyor 2nd Grade.
Mr. H. Todd, Asst. Sur. 2nd Grade.
" T. Kinney, " 2nd "
" E. Wrixon, " 3rd "
" E. Litchfield, " 3rd "
" I. Pocock, " 4th "
And 16 Natives under training as Surveyors.

(76.) The work in the Dún being the survey of the non-forest tracts, the same scale had to be employed as that which had already been adopted for the

pari passu survey of the forest tracts, *viz.*, 4 inches = 1 mile*. This is the scale which has long been used for the British districts in the plains of the Bengal Presidency; it is sufficiently large to show the boundaries of the smallest villages, the lines of demarcation between cultivated and uncultivated tracts, and all topographical details required for the purposes of the district officer and the engineer. The numerous surveys which have been made on this scale have almost invariably been executed by native surveyors, working under close European superintendence, and Captain Thuillier's first duty was to collect a number of intelligent young natives, who could read and write, and to train them, as it was impossible for him to obtain trained men excepting on prohibitorily high salaries.

(77.) Captain Thuillier has described his operations so clearly and minutely, in the portions of his narrative report which are pointed at pages 36—$_a$ and 37—$_a$ of the appendix, that it is only necessary for me to remark that, though there is no great show of topography—as was scarcely to be expected under the circumstances—much good work has been done, the fruits of which will be more apparent hereafter than they are at present. An area of 529 square miles has been well covered with trigonometrical points as a basis for the future topographical operations, 1,372 points in all—or about 2·3 per square mile—having been fixed, of 156 of which the heights were also determined. The aggregate length of the boundary lines which were traversed amounts to 848 linear miles. The topography embraces an area of 63 square miles.

(78.) In running the traverses, and in other portions of the operations which are rather mechanical than artistic, the native lads soon become fitted for rendering serviceable aid; but to teach them the art of delineating the features of the ground by the method of plane-tabling was of course a far slower matter. While this was being done some portions of the district were plane-tabled by the European surveyors, and it was found that skilful draughtsmen, who had turned out their 100 square miles per mensem in the hills of Kumaon and Garhwál, on the 1-inch scale, were not able to accomplish more than 15 square miles, in the same time, on the 4-inch scale, in the Dún. Thus—though the scale for the future operations which are mentioned in para (72), will probably not be the 4-inch but the 2-inch, which has already been employed in the Revenue Surveys of the

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* I may here be permitted to observe that the fixing of a scale, at the outset, for the Forest Surveys, was a matter of no small difficulty; the opinions of a considerable number of forest officers, employed in different parts of India, were taken on the subject, and there was a general concurrence of opinion that two classes of maps were required, namely,

(1.) Working or detailed maps on a large scale;

(2.) General maps on small scales.

But there were considerable differences of opinion as to the proper scale for the working maps; several scales were recommended, varying from 4 to 12 inches to the mile, the 8-inch being the favorite.

It was doubtful whether the officers whose opinions had been received were sufficiently cognizant of the technicalities of surveying and mapping to be able to appreciate fully all that is involved in the question of scale, when the answer to that question has to govern future procedure, and to decide whether the operations to be carried out are to be rough, quick and cheap, or elaborate, slow and costly, or some thing intermediate between these two extremes. Thus it was clearly necessary that I should endeavour to ascertain the purposes of forestry for which the maps were wanted, and to find out what details of the configuration and general facts of the ground were expected to be shown on them, that I might decide on the scale which would be most suitable. Captain Bailey drew up a *precis* of the opinions of all the officers who had been consulted on this point, from which the following enumeration of the requisite details is taken.

"The formation of the ground as accurately as possible, chains of mountains, valleys, plateaux, precipices, dells,—"the altitudes of peaks, valleys and other important places—railways, tram-ways, roads, metalled or otherwise, timber "roads and slides, cattle paths and foot paths, milestones where erected,—rivers, canals, brooks, lakes, ponds, wells, "springs, drainage cuts, with weirs, dams, bridges and fords,—the perennial flow of rivers, the points from which naviga-"tion, rafting and log floating, can be carried on,—bogs, marshes, rocks, fields of boulders, sand, gravel or kunker, old "village sites, stone quarries,—towns, villages, houses, fields, meadows, grazing grounds, gardens, wood depots, camping "grounds, rest houses,—places where water may collect, and other obstacles to division and export roads,—areas subject to "inundations,—all levels which are necessary to artificial inundation. The maps are also required to form an official record "of the boundary lines and marks, and areas of forest divisions, blocks and compartments; also of the exterior and "interior boundaries of divisions, circles, ranges, blocks and compartments; the positions and distinguishing numbers "of all pillars on the boundaries of fiscal divisions and jurisdictions of private property or private rights in the forest: "the positions of seed and planting nurseries, and all blanks of any considerable extent, say from 1 to 5 acres."

This is a very formidable list of forestry requirements, and it illustrates what a variety of things may be asked for when the proposers have only to exercise their brains in stringing together a number of requisitions, and not their bodies in giving practical effect to their suggestions by lending a hand to obtain what is wanted.

The questions of scale and detail are still undecided, and they will have to be disposed of on financial considerations, and with due reference to the capabilities and value of each of the several forests; "the coat must be cut according to the cloth;" but these are matters which are not in my province. The operations in the Dún being of a tentative nature, and required for the purpose of organizing and training the forest surveyors rather than for pure forestry, I recommended the adoption of the 4-inch scale, the smallest of all suggested; this scale was approved of by the Government and has been employed up to the present time, and all details have been shown which it is capable of representing.

Hill Districts of Hazara in the Punjab—it is clear that the introduction of a cheap native agency, into a party which has hitherto been framed on the old topographical organization of European surveyors only, is essentially necessary to secure economy in the future;—and it is a well known fact, from the experience which has been gained by the Bengal Revenue Survey parties who have employed natives largely, that the requisite economy may be secured without impairing the quality of the results, provided always that the number of native surveyors is not greater than can be efficiently supervised by the Europeans.

NO. X.—TOPOGRAPHICAL.

HIMALAYAN SURVEYS IN KUMAUN AND GARHWAL.

PERSONNEL.

E. C. Ryall Esq.
Mr. Mc A'Fee.
„ E. Litchfield.
„ I. Pocock.
„ Mc. Carthy.

(79.) For the reasons already stated in para (75), it was not desirable to resume operations until the commencement of the spring of 1874. Early in April Mr. Ryall marched from Dehra Dún with four assistants, and proceeded *viâ* Almora to the ground to be surveyed, which lay among the upper valleys of the Rámganga, Sarju, Gori and Rálam rivers. Operations were carried on until the beginning of July, by which time Mr. Ryall had triangulated an area of about 460 square miles, and his assistants had completed the topography of about 534 square miles, much of which was closely supervised by himself. By this time the rainy season, which this year commenced at an unusually early date, had set in with such persistence that it was useless to remain out in the field any longer, for even in the breaks of rainfall the ground was mostly hid from view by mist and cloud-caps. The party consequently returned to Almora and recessed there, as that was the nearest point to the field of operations at which houses were to be met with. Immediately after the cessation of the rains they returned to their field duties, and made excellent progress; but as the subsequent operations appertain to the year 1874-75, and must therefore be described in the next annual report, they need not be further noticed here.

NO. XI.—TIDAL OBSERVATIONS.

DETERMINATIONS OF MEAN SEA LEVEL IN THE GULF OF KUTCH.

PERSONNEL.

Captain Baird, R.E., Offg. Deputy Superintendent 1st grade.
Mr. T. Rendell, Assistant Surveyor 1st grade.
Nursing Dass and three other Sub-Surveyors, &c.

(80.) In my last report I described the arrangements that were being made for carrying out the Tidal Observations which I had been directed to undertake in the Gulf of Kutch, with a view to ascertaining whether secular changes were taking place in the relative level of the land and sea at the head of the gulf. The coasts had been carefully reconnoitered by Lieutenant (now Captain) Baird, who, after long searching, had found three places which appeared to be well adapted for the erection of tidal stations, being situated at points near which there is always a considerable depth of water and to which the tide has free access; the foreshores of the gulf had been found to be generally far from promising, consisting mainly of long mud banks, which often stretch for miles out into the sea and are left bare at low water, when they are intersected by innumerable tortuous and shallow creeks whose shifting channels would be very unfavorable positions for tide-gauges. But at Hanstal Point—near the head

of the gulf,—at Nowanár Point—half way up, on the northern or Kutch coast,—and at Okha Point, on the southern coast—opposite the Island of Beyt and on a line with the entrance to the gulf,—positions had been found which fulfilled the requisite conditions for tidal stations, and were believed by Captain Baird to be the only suitable points to be met with on the coasts of the gulf.

(81.) It happens however that none of these points are situated in ports or harbours, where the piers, jetties, landing stages or docks, which have been constructed for the requirements of the shipping, present great facilities for setting up tide-gauges in the vicinity of deep water, so that it is almost invariably the custom to erect them in such places; these points on the contrary are all situated at some distance from the nearest inhabited localities, and present no facilities whatever; for not only building materials and food for the workmen but fresh water also have to be brought to them from considerable distances. It was thus imperative that the plan of operations should be of the simplest nature possible, so as to be carried out with the least cost and greatest expedition.

(82.) A tide-gauge may either be set up on a staging in the sea, over deep water, or on shore, over a well which is connected by a system of piping with the deep water. *Cæteris paribus* the former position is decidedly the best of the two, and if any jetties or piers had been available for the operations I would certainly have had the stations erected on them. But under existing circumstances it was only possible to set up the tide-gauges over deep water by erecting stagings for them in the sea; and they would have had to be very strongly built, for they would be required to withstand the full force of the sea, without undergoing any displacement whatever, and that not for a short time only but for several years, so as to include both the first series of tidal registrations, taken to determine the present relations of the land and sea, and the final series, which will have to be taken to determine the future relations several years hence. The stagings would moreover have had to be connected with the land by piers, in order to permit of ready access to the instruments at all times. The cost of such stagings and their connecting piers would however have been very considerable and have far exceeded the funds available for the operations; I was therefore compelled, though with some reluctance, to decide on having the tide-gauges set up on shore, over wells sunk near the high water line and connected with the sea by piping.

(83.) Captain Baird spent the recess of 1873 at Bombay in preparing for the operations of the field season of 1873-74. The several self-registering instruments which were to be employed—the tide-gauges, the aneroid barometers and the anemometers, or anemographs—were overhauled and put into good working order. The gauges were tested by being employed to register the tides in the harbour of Bombay for several weeks continuously, and were set up over wells connected with deep water by piping, in order that the experimental observations should be taken under precisely similar circumstances to the actual observations.

(84.) The wells are iron cylinders, with an internal diameter of 22 inches which slightly exceeds the diameter of the float; the cylinders were made up in sections of 50 inches in length, the lowest of which is closed below with an iron plate, and the whole, when bolted together, forms a water-tight well, into which water can only enter through the piping for effecting the connection with the sea. The piping is of an internal diameter of 2 inches, which has been computed to be sufficient to permit of the transmission of the tidal wave to the well without sensible retardation. Iron piping is laid from the well to the line of low water; it is brought vertically up from the bottom of the well nearly to the surface of the ground, and is then carried down to the sea, where flexible gutta percha piping is attached and carried into the deep water. The outer piping terminates in a 'rose,' which is suspended a few feet above the bed of the sea by a buoy, in order to prevent the entrance of silt as much as possible, and it can be readily detached from the iron piping whenever it has to be cleaned.

(85.) The level of the water in the well should obviously always coincide with that of the sea, and if it does not do so the registrations of the gauge are worthless; thus an imperative necessity arises for comparing the inside and

outside levels, from time to time, in order to remove all doubt as to the efficiency of the communication between the well and the sea. For this purpose an ordinary gauge was attached to a pile driven into the bed of the sea, and its zero was connected with that of the self-registering gauge over the well, by spirit levelling, and thus a comparison of the levels could be readily made whenever desirable. On taking these comparisons during the trial observations at Bombay, Captain Baird was surprised to find that, while the levels were generally identical, there were occasional large differences which at first could not be accounted for; eventually however he succeeded in tracing them to the accidental presence of air inside the piping. He soon devised a simple method of expelling the air and restoring the requisite identity of level, by fixing a stop-cock, for the exit of the air, at the vertical bend, where the iron piping—after rising from the bottom of the well to within a few inches of the surface of the ground—begins to slope downwards towards the sea; this bend has necessarily to be made at a point a little below the level of the lowest high water tide, and consequently, on opening the stop-cock at high water, all the air inside the pipe is of course immediately expelled, and then the water inside the well at once assumes the same level as that of the sea. But for this expedient it would have been impossible to carry on the operations continuously for any length of time, as there was found to be a decided tendency for air to collect in the pipes. It is most fortunate that this was discovered during the experimental observations at Bombay, for there stop-cocks could be readily constructed and attached to the piping, whereas at either of the stations in the gulf it would have been impossible to have had this done.

(86.) While in Bombay Captain Baird also constructed three portable observatories, for erection at the tidal stations, which were made in such a manner as to be readily put together, or taken to pieces and re-erected at any other place where they might afterwards be required.

(87.) On arrival at the stations where the tide-gauges were to be erected, the first thing to be done was to make an excavation for the iron cylinder. At Hanstal firm soil was met with, which permitted of the hollowing out of a hole of sufficient depth, without any measures to prop up the sides and prevent them from falling in. But at Okha and Nowanár, where the soil is sandy, it was necessary to sink small masonry wells of a sufficient diameter to receive the iron cylinders and the vertical shaft of the piping; they were sunk in much the same manner as the wells which are so frequently used in this country for the foundations of bridges and aqueducts; the operations were considerably facilitated by the employment of Bull's patent dredgers, for scooping out the soil under the sinking masonry, which had been found so useful in the construction of the Oude and Rohilcund Railway that Captain Baird had been directed to provide himself with some for his operations.

(88.) Okha Station—being near the mouth of the gulf and the nearest to Bombay, where all the preliminaries were made—was selected as the first to be taken in hand. There all the instruments and stores, and the European assistants—including Mr. Peters a skilled artificer employed on the Bombay Harbour Works, whose services had been obligingly placed at Captain Baird's disposal for a short time—and the native establishment, were sent direct from Bombay in a pattimar (or native sailing vessel). Meeting with contrary winds, the "Kotia Romani" took such a long time to perform the voyage that Captain Baird began to fear that she must have gone down with all hands on board; at last however she arrived, with her passengers and crew nearly starved, for they had taken with them only a week's provisions for a voyage which lasted fourteen days. On the 5th November the landing of the stores and the sinking of the masonry well was commenced; the well had got down to the requisite depth, 25 feet, by the 4th December, and by the 20th the cylinder had been set up, the piping connecting it with the sea had been laid out into deep water, the observatory was erected, and the several self-registering instruments—a tide-gauge, an anemometer and an aneroid barometer—were all in position and ready for the preliminary trial of their performances. By the 23rd every thing was complete, the instruments

were all working well, and Captain Baird was about to proceed to the next station, when an unanticipated mis-adventure occurred which, though intensely annoying at the time, was useful in indicating that it was essentially necessary to take special precautions for the protection of the piping.

(89.) About 3 A.M. on the morning of the 24th, a large native boat was seen drifting from her anchorage towards the station; the crew were all asleep, and before they could be aroused by the sentry on guard, the boat had dragged her anchors across the flexible piping, broken it in two places, and carried away the buoys and the anchor to which they were attached. Being on the spot and provided with spare piping, Captain Baird was able to rectify the damage in a few hours; he also made arrangements for protecting the piping by laying out and anchoring hawsers around it, to intercept passing boats and prevent them from drifting into mischief. Similar measures were carried out at the other stations, and these precautions were essential to the success of the operations; for each station would ordinarily be left under the charge only of the native subordinate employed in winding the clocks of the tide-gauges and the other self-registering instruments, in changing the papers on their barrels and in generally looking after their performances; consequently any injury to the piping would cause a suspension of the tidal registrations for probably a fortnight or more, until Captain Baird could either come in person or send a European assistant to repair the damage, and the break of continuity thus occasioned would greatly impair the value of the observations.

(90.) While engaged in completing what had to be done at Okha, Captain Baird sent his assistants in advance to Hanstal and Nawanár to sink the wells, erect the observatories, and get every thing ready for him to set up the instruments. The extracts from his report, which will be found in the appendix, give full details of the operations at each station, and I need not dwell on them, as they were generally similar to those at Okha of which I have given the principal out-lines.

(91.) The operations were carried on under many and great difficulties. No small amount of risk was incurred by Captain Baird and his assistants when crossing the gulf in native sailing vessels, which had to be done frequently, whenever their presence was needed at either of the stations, both during its construction, and afterwards when accidents occurred, or defects in the working of the instruments had to be rectified, which needed European supervision. On one occasion the pattimar, while under full sail with a stiff breeze, struck on a sand bank and heeled over, and would probably have capsized altogether but for the vigorous action of Mr. Peters, who immediately took command and directed the nacoda and crew to do whatever was necessary for the protection of the vessel. These risks would have been avoided had I assented to a proposition frequently urged on me by Captain Baird, to accept the loan of a small steamer belonging to the Department of Public Works in Bombay, which had been offered, on the condition that we should pay the wages of the Captain and crew and the cost of the coal;—but this would probably have trebled the cost of the operations and therefore the proposal could not be entertained.

(92.) Huts had to be built and iron water tanks provided at each station, for the native surveyor and the underlings who were placed in charge of the instruments, and for the men of the guard furnished by the Durbar of the Native State in which the station is situated. Arrangements had also to be made to supply these men with food and drinking water, which at Hanstal was no easy matter, for the nearest point whence these necessaries of life could be obtained was about 25 miles off. At each station a line of post runners had to be established, to the nearest point on the main postal lines of cummunication, as it was essentially necessary that Captain Baird should receive daily reports from the men in charge of the observatories.

(93.) A singular political difficulty arose at Hanstal. The station is situated in lands which are claimed by both the Rao of Kutch and the Chief of Náwanagar; each of the Durbars vied with the other as to which should be the

first to supply the requisite guard, hoping thereby to establish an acknowledgement on the part of British Officers to its claims; the guard from Náwanagar was first in the field; but not long afterwards, and during the absence of Captain Baird, some armed men landed from Kutch, apparently with the intention of ousting the Náwanagar men; but after much altercation and a slight scuffle, they re-embarked and gave no further annoyance.

(94.) At short distances round each station three blocks of stone were sunk in the ground, to serve as bench-marks for future reference, and each of them was carefully connected with the zero of the tide-gauge. Bench-marks were also placed in position on the lines over which, next year, the levels will be carried which are required to connect the tidal stations together and determine their present differences of level, and again hereafter, when a sufficient interval has elapsed to allow of the rising or sinking of the surface of the ground to an appreciable extent.

(95.) The regular tidal registrations were commenced at Okha by the end of December, at Hanstal by the end of March and at Nawanár by the end of April. It was hoped that they might have been carried on continously for at least a year, or perhaps longer, at each station, in order to furnish the requisite data for investigations of the separate influence of each as well as the combined of all of the principal tidal constituents, and the least that is needed for this purpose is a series of observations extending over a year. During this time the errors of the clocks for driving the barrels of the self-registering instruments would have to be frequently determined and the clocks corrected; the instruments would also have to be examined and cleaned, and possibly repaired also, and the relations between the curves on the diagrams and their zero times would have to be carefully redetermined, from time to time; and all this would have to be done either by Captain Baird or by his assistant Mr. Rendell.

(96.) A programme was therefore drawn up for the periodic inspection of the tidal stations, and Captain Baird arranged that he and Mr. Rendell should make tours of inspection in turns. It was calculated that the time required for a tour, embracing all three stations, would be about a month, from the date of leaving to that of returning to the recess quarters; these had been established at Rajkot, the nearest town to the gulf where house accomodation, suitable for Europeans, could be obtained. Anticipating that during the monsoon months the weather at the tidal stations might be found too cloudy to permit of astronomical observations for determining the clock errors, Captain Baird provided himself with two portable chronometers (a siderial and a mean-time) which were rated at Rajkot and carried about on the tours of inspection, for comparison with the clocks.

(97.) The inspection of the observatories necessitated a great deal of hard marching, and entailed much exposure and privation. Even so early as in the month of May, before the setting in of the monsoon, the Runn of Kutch was covered with water, from six inches to a foot in depth, which had to be waded through for many miles distance to reach the station at Hanstal. At such seasons travellers usually cross the Runn by riding on the camels of the country; these animals are bred in large numbers along the borders of the gulf, and are accustomed from their birth to wonder about the swamps, browsing on the mangrove bushes, and thus they learn to walk with ease, and keep their feet, on ground which would be impassable to most other camels. Of his journey with Mr. Rendell to Hanstal in the month of May, Captain Baird writes, "our only "land marks in the whole of the last 14 miles were two small mounds of earth "thrown up—when there were postal chowkees there—at 4 or 5 miles apart, and "the observatory itself; we both felt a curious sensation as if we were being "carried out to sea, which was occasioned by seeing small branches of scrub "floating on the surface of the water and being driven by the wind inland; and "once, with the exception of one of the mounds above mentioned in the distance, "there were no fixed objects visible to destroy this optical illusion." Later on, when the monsoon set in, the difficulties of locomotion were greatly increased; direct communication with Nawanár, by crossing the gulf in a sailing boat,

became impossible, as none but native vessels were available for the purpose, and they could not venture to cross in the strong gales of wind which then prevailed; thus to reach the tidal station at that place it was necessary to make a very long detour round the head of the gulf, crossing the Runn at its narrowest point, opposite to Wawania. Moreover the common unmetalled roads in a black soil country, as is the western portion of Kattywar, become all but impassable during the rains; and thus Captain Baird was often unable to get over the ground more expeditiously than at the rate of a mile an hour. Between the 7th July and the 8th September he was actually 38 days in the field, and marched nearly 800 miles, under most adverse circumstances.

(98.) I will now notice the general working of the tide-gauges at the three stations. At Okha the registrations have gone on most satisfactorily up to the time of the latest report received from Captain Baird; there appears to have been only a single break in the continuity of the record, and it only lasted for five hours and is consequently quite immaterial. At Hanstal there have been several short breaks, caused, sometimes by the driving clock getting out of order, but more frequently by the deposit of fine mud in the well and in the piping, notwithstanding the precautions which had been taken to keep the rose at the extremity of the piping high above the mud banks; this necessitated the occasional suspension of operations while the mud was being removed, and care was always taken to make the break between the times of high and low water, whenever possible; thus the record of the highest and lowest points of curves has been secured in almost all instances, the breaks may usually be interpolated between them, and the instances in which this has not happened are so few that Captain Baird believes they will not sensibly influence the final results. The foreshore at Okha being sand and rock without mud, there has been no tendency there for the piping to become choked. Both at Okha and Hanstal air was found to enter the iron piping, whenever the latter was laid bare by the action of the surf, which frequently happened; but it was readily expelled at high water, by opening the stock cock which has already been described as having been attached to the piping for that purpose.

(99.) At Nawanár however matters went on less prosperously. At the July inspection of this station, Captain Baird found every thing apparently in good order; the curves on the diagram of the tide-gauge seemed at first to be all that could be desired; but it was soon evident that they were erroneous, for the level of the water in the well differed very sensibly from the sea level. On examining the piping, the extreme end was found to be buried in sand above the low water line, at a spot where, a few weeks before, there had been a depth of 20 feet of water at low tide, and which was now left bare for some time daily. On further examination it was ascertained that the configuration of the foreshore had entirely changed, and an extensive sand spit had formed on the line of the piping; this had been caused by the drift from a belt of sand hills to the south, under the influence of the strong winds which blow from the south-west during the moonsoon, the registered velocities of which were as much as 860 to 890 miles daily, for several days preceding the misadventure. There is reason to expect that the original configuration of the foreshore may be restored, within a few weeks after the cessation of the monsoon. But the position has been clearly proved to be unsuitable for continuous tidal observations, extending over a long period; for it is only during the months of fine weather, between November and May, that observations can be carried on there, otherwise than by setting up the tide-gauge on a staging erected for it out in deep water, the cost of which would be inadmissible.

(100.) The preliminary results of the observations up to the end of September have been worked out by Captain Baird, and it appears that the greatest range of the tide is

14·8 feet at Okha
19·6 „ Nawanár
and 21·2 „ Hanstal,

or 2 to 4 feet more in each instance than the ranges given in the Marine Charts. Very fairly approximate values of the progress of the tidal wave, up and down the gulf, have been obtained, shewing that

High water occurs at	Nawanár	1*h*	5*m*	after Okha
„	Hanstal	1	40	„
Low water occurs at	Nawanár	1	36	„
„	Hanstal	2	53	„

(101.) The curves of the self-registering aneroid barometers were compared four times daily with a mercurial barometer, and the differences met with—after allowing for index errors—were usually so trivial and unimportant that every confidence may be felt in the general accuracy of the curves. The aneroids are of a delicate construction and are liable to get out of order, but as spare ones were available no break of importance occurred at either station.

(102.) The anemometers were less satisfactory in their working, probably because they were so much more exposed to the vicissitudes of the weather. The long continuance of winds coming from the same quarter caused the direction gear to clog, and until this was discovered the recorded directions are to some extent incorrect. On the other hand the velocity gear was kept in constant action by the strong winds which were prevalent. Several severe gales were recorded. The greatest velocities registered in 24 hours were

620	miles at	Okha	on the 20th June
890	„	Nawanár	26th „
1130	„	Hanstal	5th August;

on the latter date the anemometer at Hanstal recorded 270 miles in three hours, between 9 A.M. and noon. Captain Baird is not entirely satisfied with the performances of these instruments; but, considering their small size (for the sake of lightness and portability), and their exposure to fierce winds, to rain and, worse than all, to the constant oxidising influence of the sea, I think it improbable that any instruments would, under similar circumstances, have given much better results.

(103.) Rain gauges were set up at each station; the total rainfall during the monsoon was

10·75	inches at	Okha
13·61	„	Nawanár
18·40	„	Hanstal
21·91	„	Rajkot (40 miles inland).

(104.) It will be seen that, so far, a greater range of tide, a greater velocity of wind and a greater rainfall, have been registered at the head than at the mouth of the gulf, and intermediate values at the midway station of Nawanár.

(105.) The scientific value of the tidal observations will be greatly increased by the contemporaneous observations of the barometric pressure, the velocity and direction of the wind, and the amount of rainfall. I am not aware of any series of tidal observations which are better furnished than these with the requisite data for separating local atmospheric influences from the true tidal constituents, which are caused by the varying positions of the sun and moon.

(106.) Captain Baird has laboured most heartily and skilfully in carrying out the operations and doing all that could be done to secure their success; they have proved to be so arduous, and have entailed so much exertion and exposure that I am almost disposed to regret that they were ever undertaken. The most trying of his duties was the inspection of the stations during the monsoon, which was done entirely by himself, as he generously gave his assistant leave of absence, on urgent private affairs, at that time.

(107.) The latest reports state that all was going on well, at Okha and Hanstal; Captain Baird had proceeded to Nawanár to rectify matters there, after which

he was to commence the line of levels for connecting the three stations. He has been instructed to dismantle the three observatories before the commencement of the monsoon of 1875, by which time it is hoped that upwards of a year's observations will have been taken at Okha and Hanstal, which will suffice for an investigation of all the principal tidal constituents at those stations; and some months observations will probably have been completed at the intermediate station of Nawanár, which should be of considerable value, though inferior to that of the observations at the two other stations.

NO. XII.—GEODETIC.

THE PENDULUM OPERATIONS.

PERSONNEL.

Captain W. J. Heaviside, R.E., Deputy Superintendent 3rd Grade.
Mr. H. E. T. Keelan, Surveyor 3rd Grade.

(108.) When my last report was sent in, Captain Heaviside was in England, taking observations at the Kew Observatory, with the Royal Society's and the Russian pendulums, in order to complete the original programme of operations, and link the work done in India, by the late Captain Basevi, with that done in Western Europe, Russia and other parts of the globe. General Sir E. Sabine, to whom the initiation of Captain Basevi's operations was in great measure due, took much interest in the work which was being done at Kew and rendered much assistance to Captain Heaviside.

(109.) As the results by the pendulums of the Royal Society are differential only, and do not afford a value of the length of the second's pendulum—the originally adopted Imperial Standard for British measures of length—Sir E. Sabine proposed that such additional 'experiments' should be made at Kew, as would be requisite for the conversion of the several comparative results, in India and elsewhere, into absolute values. He pointed out that hitherto there were in Britain only two localities—No. 2 Portland Place in London and the Royal Observatory at Greenwich—in which the absolute length of the seconds pendulum had been determined; the first of these had been sold into private hands, and was no longer available for public purposes; and the second had been appropriated for other purposes, so that the Astronomer Royal could not surrender it, nor indeed arrange to have the pendulum experiments conducted in any part of the Greenwich Observatory, and consequently he proposed that a temporary building should be erected for them, in the grounds of the surrounding Park, and pulled down on their completion. But at Kew provision had long been made for such experiments; the room was available in which the Royal Society's differential pendulums had been swung before they were taken out to India, and were then being re-swung on their return. Sir E. Sabine suggested that the absolute pendulum, which had been employed by Captain Kater in his determination of the length of the seconds pendulum, and which was then at the Kew Observatory, should be swung by Captain Heaviside on the completion of his own operations. I felt bound to assent to a suggestion emanating from so high an authority, and consequently directed Captain Heaviside to take the requisite swings with Captain Kater's pendulum, and these he has duly completed.

(110.) It remained however to compare the unit of length thus determined with the Standard Yard, the present national standard of length; and this could be no where done better than in the Ordnance Survey Office at Southampton, where special operations have been carried on for some years past for comparing

the several national standards of length, and all the requisite apparatus is available. Lieutenant Colonel A. R. Clarke, R.E., by whom the comparisons of standards had been conducted, kindly undertook to measure the distance between the knife edges of the Kater pendulum, in the condition in which it was made over to him on the completion of the swings at Kew, and this has relieved Captain Heaviside of what might have been a very troublesome and tedious duty.

(111.) On the completion of his operations Captain Heaviside gave back to the Royal Society the invariable pendulums, the clock and other instruments which had been lent for the experiments in India, and—with the approval of the Secretary of State—he presented the Society with the air-pump and vacuum apparatus and other instruments which had been subsequently obtained at the cost of the Indian Government. He was asked by the Astronomer Royal to accompany the expedition which was about to be sent to Kerguelin Island, for the observation of the Transit of Venus, and take pendulum experiments on that island; but, believing that the Indian Government had done quite enough for pendulum science, and being anxious for Captain Heaviside's speedy return to complete the reduction of his and Captain Basevi's observations, I demurred to his being sent to Kerguelin Island, and suggested that an officer might be deputed by the Home Government for the purpose, with the pendulums and apparatus which had been used in India, the practical manipulation of which might readily be taught him by Captain Heaviside. The proposal however appears to have fallen through, for I have heard no more about it.

(112.) After taking a short leave of absence in England on the completion of his operations, Captain Heaviside returned to India and arrived at the Head Quarters in October last; he has ever since been employed in reducing the observations, and preparing them and the results for publication, with the assistance of the Computing Office. This work will entail a considerable amount of labour, but great care is being taken to eschew all theoretical refinements, however tempting, which are liable to increase the number of the calculations without sensibly affecting the accuracy of the results, and in printing the observations to restrict the details to what is essentially necessary for the verification of the deductions.

(113.) The Secretary of State for India having expressed a desire to be furnished with the results of the operations as soon as possible, a table is given, on the following page, of the results of the whole of the observations with the Royal Society's pendulums. Comparisons of the actual with the theoretical values—the latter computed with an assumed ellipticity of $\frac{1}{300}$—are given in the right hand column. It will be seen that at the ocean station and at most of the coast stations, the actual number of vibrations exceeds the theoretical number, and that an increase has invariably been met with in proceeding, along a parallel of latitude, from the interior of the main land to the ocean; conversely a marked decrease is met with in proceeding up the main land to the Himalayas, and it is very considerable at the station of Moré, on the table-lands of the Himalayas, at an altitude of 15,427 feet above the sea; there is thus incontestible evidence in confirmation of the hypothesis of a diminution of density in the strata of the earth's crust which are under continents and mountains, and an increase of density in the strata under the bed of the ocean, and it is clear that elevations above the mean sea level are accompanied by an attenuation of the matter of the crust, and depressions by a consolidation.

(114) The reductions of the swings with the Russian pendulums and Captain Kater's pendulum are not yet sufficiently advanced to enable any conclusions to be drawn regarding the results.

Preliminary Abstract of approximate mean results with the Royal Society's Invariable Pendulums Nos. 4 and 1821.

Number.	Stations.	Geodetic Co-ordinates. North Latitude.	East Longitude.	Height in feet above sea level.	Number of Vibrations in a Mean Solar Day. By Observation.	By computation in terms of Punnæ with an ellipticity $=\frac{1}{300}$	Observed − Computed.
	Base Station.	° ′	° ′				
1	Kew Observatory, (1865)	51 28	− 0 19	15	86114·03	86113·55	+0·66
	„ „ * (1873)				14·38		
	Indian Arc Stations.						
2	Punnæ, ...	8 10	+77 41	44	85978·29	...	...
3	Kudankulam, ...	8 11	77 45	166	78·44	85978·32	+0·12
4	Mallapatti, ...	9 29	78 3	343	78·83	79·89	−1·06
5	Pachapáliam, ...	11 0	77 40	971	80·13	82·00	1·87
6	S. W. end Bangalore Base, ...	13 1	77 37	3116	81·64	85·27	3·63
7	N. E. „ ...	13 4	77 42	3007	82·35	85·40	3·05
8	Namthabad, ...	15 6	77 36	1219	86·36	89·19	2·83
9	Kodangal, ...	17 8	77 41	1972	91·23	93·52	2·29
10	Dámargida, ...	18 3	77 43	1934	91·16	95·64	4·48
11	Somtánna, ...	19 5	77 42	1711	95·70	98·12	2·42
12	Badgáon, ...	20 44	77 39	1120	86000·18	86002·35	2·17
13	Ahmadpur, ...	23 36	77 43	1681	08·00	10·34	2·34
14	Kaliámpúr, ...	24 7	77 42	1765	10·29	11·85	1·56
15	Pahárgarh, ...	24 56	77 44	1641	10·58	14·31	3·73
16	Usira, ...	26 57	77 40	812	18·81	20·64	1·83
17	Datairi, ...	28 44	77 41	719	23·66	26·51	2·85
18	Kalfána, (1866)	29 31	77 42	826	24·38	29·16	4·88
	„ (1870)				24·01		
	„ * (1873)				24·44		
19	Nójli, ...	29 53	77 43	881	24·94	30·45	5·51
20	Dehra Dún, ...	30 20	78 6	2289	24·71	31·98	7·27
21	Mussooree, ...	30 28	79 12	6920	25·67	32·42	6·75
	High Table-land Station.						
22	Moré, ...	33 16	77 54	15427	86019·24	86042·43	−23·19
	Coast Stations.						
23	Alleppy, ...	9 30	76 20	6	85981·25	85979·90	+1·35
24	Aden,*	12 47	45 2	5	87·35	84·88	2·47
25	Mangalore, ...	12 52	74 49	7	84·29	85·01	−0·72
26	Madras, ...	13 4	80 17	27	84·47	85·37	0·90
27	Cocanáda, ...	16 56	82 18	9	93·58	93·09	+0·49
28	Colába,* (Bombay)	18 54	72 51	35	86000·64	97·66	2·98
29	Calcutta, ...	22 33	88 24	18	8·14	86007·29	0·85
	Ocean Station.						
30	Minicoy, ...	8 17	73 2	6	85982·33	85978·43	+3·90
	Other Stations.						
31	Mecan Meer, ...	31 32	77 25	706	86031·78	86036·18	−4·40
32	Ismailia,* (Egypt)	30 36	32 16	32	31·48	32·90	1·42

The first observations at the Kew Observatory were by Mr. Lœwy; the observations marked thus* were by Captain Heaviside, and all others by Captain Basevi.

The results 'by observation' are the corrected results, after the application of the usual reductions to the observations, *viz.*, 1st the reduction to an infinitely small arc, 2ndly that to a standard temperature (72° Fahrenheit) 3rdly that to a vacuum, and 4thly that to the mean sea level. The 2nd and 3rd of these reductions have been made with preliminary values of the factors of temperature and pressure, which may differ somewhat from the final values: consequently all the results are preliminary only and will have to be corrected, but the corrections cannot materially affect the differential results in the right hand column.

NO. XIII.—GEOGRAPHICAL.

TRANS HIMALAYAN EXPLORATIONS.

(115.) The second appendix to this report contains three papers, the 1st a narrative of an exploration of the Namcho or Tengri Núr Lake, by a native explorer, during 1872, drawn up by Lieutenant-Colonel Montgomerie; the 2nd a memorandum, by the same officer, on the results of the same exploration; and the 3rd some extracts from the narrative by a native explorer of his journey from Pitoragarh (in Kumaun) *viâ* Jumla to Tadum, and then down through Nepaul, along the Gandak river, to British territory.

(116.) Of these papers the two first, which are illustrated by a map, were prepared by Colonel Montgomerie in England, from the original journals which he took with him for the purpose, as mentioned in para. (111.) of my report for last year; they describe an exploration, through an almost unknown portion of Great Thibet, from Shigatze across the Brahmaputra river to the northern shores of the great Namcho Lake, the furthest point of which lies about 100 miles to the north of the town of Lhása. The third, which is also illustrated by a map, gives an account of journeys through regions some of which were unknown and others known only from the information contained in rude itineraries; thus the route from Pitoragarh to Jumla was over new ground; that from Jumla to Muktináth and Tadum over ground of which rude information was already forthcoming, but it required additions and rectifications; the route through Nepaul, from Muktináth down the Gandak river to British territory, was practically new also, and is a useful contribution to our knowledge of the geography of the Nepaulese Dominions.

(117.) But the quarter in which the most extensive and valuable geographical acquisitions have been made, during the present year, is in Kashgharia and the western portions of Eastern Turkestan, in the Pamir or Bám-i-dunia (Roof of the World), and in the regions of the Upper Sources of the Oxus. In my last report I stated that, having been called on to depute an officer to accompany Mr. (now Sir Douglas) Forsyth on his mission to the court of the Atálik Gházi, I had selected Captain Trotter for the purpose, supplied him with all the requisite instruments, sent four of the Pandits—the trained native explorers—with him, and done all else that was in my power to secure the success of the mission from a geographical point of view. And the result has been that considerable additions and rectifications have been obtained; and Captain Trotter may well be congratulated on the success with which his labours have been crowned, notwithstanding that they were carried on under numerous and great difficulties, in consequence of their having been necessarily conducted in mid-winter, a most inclement season of the year for travellers in the highly elevated plateaux of Central Asia.

(118.) To the north of Kashghar Captain Trotter carried a survey through the Artysh valley up to the Russian frontier, at Lake Chadyr Kul, and, though he was disappointed in his expectation of being able to strike off eastwards to the Terekty pass and return by the road from there to Kashghar, he has satisfactorily succeeded in connecting his work with that of the Russian geographers. He subsequently made a survey of a considerable portion of the road towards Úsh-Turfán, to the north-east, and reached the Belowti pass, which is 150 miles from Kashghar and about 90 miles from Úsh Turfán. Meanwhile Captain Biddulph surveyed the road from Kashghar eastwards to Marálbáshi. But no opportunities were afforded for reconnoitering any portion of the long belt of almost unknown country at present ruled by the Atálik Gházi—which extends eastwards for a distance of probably over 700 miles beyond the points reached by Captains Trotter and Biddulph—nor of the road to the west leading into Khokand *viâ* the Terek pass.

(119.) Captain Trotter afterwards made a survey of the route which proceeds from Yangi Hissár south of Kashghar to Tashkurgháu, and then westwards

viâ Aktásh over the Little Pamir, and ascertained that the lake on this table-land, called Barkut Yassin by the Mirza in his journals—extracts of which are given in my report for 1869-70—is one of the sources of a river which is here called the Aksú and afterwards the Murghábi, and which joins the Oxus near Wámur, and is in all probability the principal source of that river, as has already been conjectured by Colonel Yule. Captain Trotter continued his survey down to Kila Panja, the little town in Wakhán from which one of the principal sources of the Oxus derives its name. This was the furthest point reached by Captain Trotter to the west; but fortunately he was able to send one of his native surveyors down the Panja river for a considerable distance. The man first went to Ishkashim, so far travelling a route which is well known from the journals of Wood and the Mirza; and then he struck northwards into a region that was altogether unknown, and followed the downward course of the Panja river for a distance of nearly 100 miles, finding its direction to be in reality very different from what has hitherto been conjectured and represented on the best maps of these regions; he reached Kila Wámar, in Roshán, but was unable to go down the river any further. An exploration has however been since made from Fyzabad and Koláb up the river, to a point which is believed to be at no great distance from Kila Wámar, by Colonel Montgomerie's Havildar, who is now returning from Kábul with his journals; he writes that he has suffered great hardships and lost some of his papers; but if enough evidence is forthcoming to determine the course of the Oxus from Kila Wámar down to the plains of Koláb, a problem which is of the highest importance, both politically and geographically, will be solved.

(120.) From Panja Captain Trotter returned to Aktásh, *viâ* the Great Pamir, passing the lake which was discovered in 1838 and named Victoria by Lieutenant Wood of the Indian Navy. From Aktásh he returned to Yarkand by almost the same route that he had already travelled. The Pandit who accompanied Captain Trotter as far as Tashkurghán, on the outward journey, returned thence by a more direct route to Yarkand, carrying a traverse survey along an entirely new piece of road.

(121.) It was not considered desirable to send the (Hindú) Pandits into localities inhabited solely by a Mahomedan population, and hitherto they had been chiefly employed in surveying various lines of routes between Ladakh and Yárkand, some new, others old but requiring rectification. But while Captain Trotter was absent in Wakhán one of these men, Krishna, was sent *viâ* Sanju to Khotan, with instructions to penetrate as far eastwards as possible. He traversed the ancient road to China, as far as the Sorghák gold fields, and then, returning to Keria, struck southwards along the road to Rudok, crossed the Kuen Luen range and the great table-lands of the higher Himalayas on the western confines of Chinese Thibet, and reached the village of Noh, which is about 20 miles to the north of Rudok; here he was stopped by the Chinese officials and nearly turned back again by the road he came, but eventually he was permitted to go direct to Leh by the Pangong Lake. His work was very carefully executed, and has stood the usual tests, furnished by comparing the route survey with the astronomical and trigonometrical determinations of position, most satisfactorily; and this is all the more important in the present instance, in that large corrections have been shown to be needed in the work of 1865-66, which has hitherto been accepted, though with some misgivings.

(122.) Captain Trotter is now at my Head Quarters, preparing a geographical memoir for Sir Douglas Forsyth's Report of the Mission, which will contain full details of his operations and those of the officers associated with him who had opportunities for visiting places which he could not go to. The report will probably be published a few weeks hence, and therefore any further notice of Captain Trotter's labours is here unnecessary.

NO. XIV.—THE COMPUTING OFFICE.

EXAMINATION, FINAL REDUCTION AND PUBLICATION OF THE OBSERVATIONS.

(123.) The Computing Office has been employed in its usual duties of carefully examining and reducing the observations, and of publishing the ultimate results of such portions as have been finally treated, and preliminary results of the portions which await further materials before they can be finally disposed of. The 3rd volume of the "*Account of the Operations &c.*" has been printed and is ready for publication, the 4th is all but complete; but as these volumes contain little else besides the numerical details of the observations and calculations and their results, I have decided to postpone their publication until the completion of the 2nd volume, which is intended to give a brief history of the operations, and a full description of the procedure which was adopted at the outset and of its subsequent modifications, of the instruments employed from time to time, and of the formulæ and methods of computation by which both the preliminary and the final results have been obtained. Of this volume about 250 pages quarto have been printed, but much more remains to be done; its preparation necessarily devolves in great measure on myself, and has to be held in abeyance when I cannot find time to devote to it; but I am in hopes that the volume will be finished by the end of 1875.

PERSONNEL.

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Sheik Saiduddeen, and 5 other Draftsmen.
5 Assistant draftsmen, also some apprentices and map colorists.

(124.) Good progress has been made with the publication of the Synoptical Volumes which give all the data required by surveyors and geographers and the public at large. Of these the following have already been issued, No. 1, the Great Indus Series; No. 2, the Great Arc, section 24° to 30°; and No. 3, the Karáchí (Kurrachee) Longitudinal Series; three more volumes are nearly ready for publication.

(125.) Considerable assistance was rendered to Captain Trotter, whose geographical operations have been reviewed in the preceding Section; all his very numerous observations for absolute and differential longitudes, and for latitudes, heights &c., have been reduced in this office, and much other work has been done for him, whereby he has been enabled to prepare his maps and reports far more rapidly than would otherwise have been possible. The completion of the pendulum operations has likewise necessitated the rendering of a large amount of assistance to Captain Heaviside, in reducing and printing the observations. In these and all the other duties of this office Messrs. Hennessey and Cole have laboured with the same skill, assiduity and zeal, which it has been my pleasing duty to bring to prominent notice in previous reports.

(126.) On the death of Captain Basevi—from exposure incurred on the high table lands of the Himalayas, while he was engaged in the pendulum operations—a subscription was raised among his brother officers and associates for a memorial of him; a sum of over R. 2,000 was subscribed, and then the question arose how it should be expended, whether in a monument or painted window to be erected in a church, or—as had been suggested—in a clock to be erected at the Head Quarters Office. His widow was consulted on the subject, and she was altogether in favour of the clock, as best serving to perpetuate his name among those by whom his labours would be best appreciated. A memorial clock, with a suitable inscription, was therefore obtained from England and it has been erected over the office portico; it strikes the quarters as well as the hours, and keeps

admirable time, and it has altogether superseded the hand-struck gong by which, for very many years, the office hours have been regulated.

No. XV.—CARTOGRAPHY.

(127.) An important series of Final Charts has been prepared to illustrate the several synoptical volumes which have been specified in para. (124). These maps are drawn on the scale of ½ of an inch to the mile, for publication by photozincography on half that scale, and great care is taken to assimilate the spellings of the names in the charts to those in the volumes, and to do all that is necessary to enable them to serve as aids to a correct understanding of the data of the triangulation of former years. Five preliminary charts, of the triangulation of the current year, have also been prepared, giving full numerical data to satisfy immediate local requirements.

(128.) Re-prints, with additions and corrections, of two of the four sheets of the 2nd edition of the Map of Turkestan have been made. Preparations have also been made for the publication of a 3rd edition of this map at an early date; each of the four sheets has been entirely re-drawn; a large amount of valuable and recent information, with which I have been favoured by Colonel Stubendorff, the Director of the Topographical branch of the Russian War Office, is being incorporated into them, and also the results of Captain Trotter's surveys; and I am only awaiting the return of Colonel Montgomerie's Havildar, now daily expected, to have the maps completed and sent to press.

(129.) In addition to the above, some progress has been made with the series of Level-Charts on which the systems of levels for Railways, Canals and other Public Works are shewn, after having been connected with the main lines of levels of this Survey and reduced thereby to the datum of the mean-sea level. The maps of Mussooree and Landour have had the recently re-demarcated boundary lines shown on them, which has been a very tedious and troublesome business, and has been protracted over several years. A map of Kumaun and Garhwál has been specially prepared for the Gazetteer of that district which is now being compiled by Mr. E. T. Atkinson, C.S., but the delays caused by having to alter the spellings of the whole of the names, in conformity with the recent orders of the Government on the orthography of Indian names, have prevented the publication of the map hitherto. Much assistance has been rendered to Captain Trotter in the compilation of his new geographical information, the maps of which have all been drawn in this office.

(130.) In the typographic office 1,220 pages, mostly quarto, have been composed and 320 copies (on an average) of each have been printed. And in the photozincographic office, 61 maps have been photographed and put on zinc, and the number of prints which have been 'pulled' is 9,207 of maps, 2,027 of charts, 3,557 of diagrams, and 28,125 of professional and office forms.

(131.) It now only remains for me to acknowledge the valuable services which have been rendered by my Personal Assistant, Mr. H. Duhan, who has relieved me of much official routine work, which would otherwise have taken up time I could ill spare for it. Of Mr. Robert Scott—whose good services in the correspondence office and as general store-keeper, it has always been a pleasure to me to acknowledge in my annual reports hitherto—I regret to have to state that this must be my last notice; he died on the 12th September, after a long and painful illness; he had served in the Department for nearly 30 years; hard working, simple minded, and ready to oblige everybody, 'good old Robert' will long be affectionately remembered and respected by all who knew him.

(132.) An abstract of the out-turn of work executed by each of the Survey parties, the results of the operations of which can be exhibited in this form,

is given on the following page. I consider the amount of progress which has been made during the year on all sides, by the Survey Parties while in the field and also in recess, and by the Offices at Head Quarters, to have been generally very satisfactory.

J. T. WALKER, COLONEL, R. E.,
Supdt. Great Trigonometrical Survey.

DEHRA DUN,
Dated 15*th February*, 1875.

Abstract of the out-turn of work executed by the Great Trigonometrical Survey Parties, during the Survey year 1873-74.

Description of Details.	1 Bangalore Meridional Series 24-inch Theodolite.	2 Assam Triangulation 12-inch Theodolite.	3 Brahmaputra Merl. Series 24-inch Theodolite.	4 Jodhpur Meridional Series 24-inch Theodolite.	5 Eastern Frontier Series 24-inch Theodolite.	7 Kattywar Topographical Survey.	8 Guzerat Topographical Survey.	9 Dehra Doon Topographical Survey, 4-inch = 1 mile.	10 Kumaon and Gurhwal Topographical Sur, 1-inch = 1 mile.	Total.
Number of Principal Stations, newly fixed, ...	13	...	11	19	8	...	...	...	...	51
Number of Principal Triangles, completed, ...	20	...	14	26	10	...	...	...	...	70
Area of Principal Triangulation, in square miles,	3,239	...	1,105	1,552	1,294	...	...	...	...	7,190
Lengths of Principal Series, in miles, ...	108	...	54	90	50	...	...	...	...	302
Average Triangular error, in seconds, ...	0·40	...	0·83	0·14	0·70	...	...	...	...	...
Average probable errors of Angles, in seconds, ±	0·14	...	0·25	0·14	0·54	...	...	...	...	...
Astronomical Azimuths of verification, ...	1	...	1	1	...	...	...	...	...	3
Number of Secondary Stations whose positions and heights have been fixed, ...	51	93	31	29	...	309	237	156	120	1,026
Number of Secondary Stations whose positions only have been fixed, ...	...	...	...	...	...	132	337	619	...	1,088
Number of Secondary Triangles of which all 3 angles have been observed, ...	13	17	17	24	...	184	335	174	29	793
Length of Secondary Series in miles, ...	...	47	37	116	...	...	...	...	...	200
Area of Secondary and Minor Triangulation square miles, ...	1,413	281	289	1,667	...	2,174	1,650	529	859	8,862
Area embraced by Triangulation to hill peaks square miles.	...	12,000	...	...	...	...	...	...	...	12,000
Number of Points fixed by intersection, but not visited, ...	61	95	21	54	...	626	369	597	...	1,823
Length of boundary lines and check lines traversed in linear miles.	...	...	...	...	...	1,235	982	848	...	3,065
Area topographically Surveyed on scale of 1-inch = 1 mile,...	...	...	...	...	...	...	...	...	534	534
„ topographically surveyed on scale of 2 inches = 1 mile in square miles, ...	...	...	...	...	...	2,366	...	...	...	2,366
„ topographically surveyed on scale of 4 inches = 1 mile in square miles, ...	...	...	...	...	...	...	690	63	...	753
Number of Revenue Survey Stations and boundary junction pillars, fixed by Triangulation,...	...	1	8	1	...	?	?	51	...	61?
„ of Principal Stations selected in advance, ...	19	...	...	14	10	...	...	...	...	43
Lengths of Approximate Series, Principal in miles, ...	64	...	...	102	112	...	...	...	...	278
Lengths of Approximate Series, Secondary in miles, ...	...	30	...	...	...	...	...	...	...	30
Number of Towers constructed, ...	5	...	...	...	...	...	...	...	...	5
Do. of Pillars and Platforms for Principal Stations, ...	6	...	...	18	8	...	...	...	...	32
Do. of Pillars constructed Secondary Stations, ...	12	14	20	10	2	...	...	46	...	104
Do. Miles of Rays cleared, ...	173	178	26	5	70	...	...	?	...	452?
Do. Miles of path-way made, ...	6	...	...	...	225	...	...	...	...	231
Do. Hill tops cleared of forests and jungle,	...	3	...	3	22	...	...	37	...	65
Do. Principal Stations whose elements were computed, ...	21	...	11	12	15	...	...	...	...	59
Do. Secondary and traverse Stations whose elements were computed, ...	90	115	32	...	...	?	1,478	?	?	1,715?
Do. Preliminary Charts of Triangulation,	2	2	1	3	...	...	...	...	...	...
Do. Of Topographical maps, ...	...	...	...	...	...	22	8	...	4	34
Do. Principal Stations placed under official protection, ...	16	13	11	19	8	...	...	...	...	67
Do. Stations protected and closed, ...	12	9	14	20	5	...	...	...	...	60
Do. Points fixed by traverse, ...	...	...	23	...	...	?	?	?	?	23?
Aneroid Determinations of height, ...	...	...	...	172	...	?	?	?	?	172?

APPENDIX.

EXTRACTS FROM THE NARRATIVE REPORTS

OF THE

EXECUTIVE OFFICERS IN CHARGE

OF THE

SURVEY PARTIES AND OPERATIONS.

Extract from the Narrative Report—dated 16th July 1874—of MAJOR B. R. BRANFILL, Deputy Superintendent 2nd Grade, in charge Madras Party.

Proposed field work 1873-74.

(2.) The proposed work for the field season 1873-74, just concluded, was the completion of the Great Arc (revision), Southern Section, which had been in abeyance for two seasons, and the commencement of the Rámnád Longitudinal Series in latitude 9° 30'.

Field work begun 2nd December.

(4.) The party marched from Bangalore on 1st November and reached Kutipárei S., the first station for observation, on 2nd December, when operations were begun with a set of circumpolar star observations for azimuth, this being a Zenith Distance (latitude) and also a Pendulum Station. Owing to cloudy weather it took ten days to complete the observations, nearly double the usual time.

(5.) It may be remarked here that one of the rays observed at this time, that between Kutipárei S. and Perumál H.S., is the longest side of any principal triangle yet observed in the Great Trigonometrical Survey of India, being 63·944 miles in length. It is probably due to the unusually clear atmosphere of the cloudy weather, that the Perumál signal-lamp, with a reflector only a foot in diameter, could be bisected at so great a distance. In March 1871, when the corresponding observations were made on this ray at Perumál H.S., a similar signal-lamp was not once visible in the course of several weeks, and even the heliotrope signal, with a full aperture of 8 inches diameter was scarcely capable of being observed through the hazy air of that season.

S. Section of the Great Arc Series completed.

(6.) Final observations were continued without interruption, and with little delay, at the twelve stations remaining, until the series was completed before the end of February, by closing upon the stations which had been connected with the Cape Comorin Base-line in 1868-69.

Loss of former station on the red sand hills.

(7.) In consequence of the disappearance of one of the two stations forming the side of junction between the Ráthápuram and Valanád polygons, it was necessary to re-observe at three of the stations already observed at and fixed. It had been necessary to occupy a point on the red sand hills or "*théri*" (for an account of which I may refer to the notes on the Tinnevelly district appended to the general report of the G. T. Survey operations for 1868-69). Mr. Mitchell who built the station there, had been directed to construct it of masonry, like a well, which he was to sink through the sand to the firm soil below, which he reported was reached at ten feet below the surface of the highest sand hillock. This depth however proved insufficient, for during the interval of four years it had been undermined and nothing remained but the *debris* to mark the spot.

Spot re-occupied with a temporary station.

(8.) No other suitable spot being available for a station it was necessary to re-occupy the site again this year: and this was done by means of a temporary station consisting of wooden piles driven deeply into the sand.

Relative site of Colonel Lambton's Red Hill Station of 1808-9.

(9.) Colonel Lambton in like manner about the year 1808-9 used a similar temporary station, presumably on the highest part of the "*théri*", or sand waste; but it appears (from the computations) to have been about 1,061 yards to the W.N.W. ½ N. of the present (1874) station and 13 or 14 feet lower.

Probable secular motion of the "théri" to the eastward.

(10.) From this it seems as if the highest part of these sand hills had shifted about 1,060 yards to the E. S. E. during the sixty years elapsed, or nearly 17 yards a year. Moreover, the point occupied by Mr. Mitchell in February 1869 was the highest point of this particular sand ridge, and of the sand hills in general. Whereas the highest point of this particular sand ridge now (February 1874) is about 30 yards farther to the eastward than it was in February 1869, having thus only travelled at the rate of 6 yards a year, but in the same direction, to the E. S. E., and it still appears to be the highest point of the "*théri.*" Some banian stakes have been planted on the chance of their taking root, and so marking the locality for future reference.

Base-line stations put into good order.

(11.) All the stations on and around the Cape Comorin Base-line were examined and found generally in a good state of preservation. The towers and observatories received the little repairs they seemed to require and the closing piles of stones and earth were restored after the five years' weathering they had sustained since first left.

Reconnoissance of the Straits of Manár.

(12.) As soon as the final observations of the Great Arc were finished, I proceeded to utilize the little clear weather that remained at the end of February by reconnoitering the Straits of Manár with a view to the practicability of a trigonometrical connection with Ceylon. The results of this reconnoissance which I reported to you met with your approbation.

(13.) The next work to be done was the Rámnád Longitudinal Series which I now took up in person. I had sent Mr. Belcham at the end of December to reconnoiter the country along the parallel of 9° 30′ and to commence laying out the Approximate Series. After a very careful and detailed examination he reported this line of country very unsuitable for the great triangulation, it being an unbroken plain of black (cotton) soil, generally under cultivation, with high standing crops, and plentifully wooded by groves of fruit trees (Tamarind, Mango and Palm), the view being also every where obstructed by long lines of high banks of tanks and irrigation channels. It was evident that every ray must be tediously traced and cleared in the regular manner, and that high towers would be required even for comparatively small triangles.

Commencement of the Rámnád Longitudinal Series.

Unsuitable nature of the country on 9° 30′.

(14.) It was impossible to lay out and prepare any stations of the new series in time for observation this season. I therefore abandoned the intention, and sent the large theodolite into store, whilst I proceeded to lay out the series myself, directing the assistants, after finally closing the Great Arc stations, to build the new stations as soon as selected.

Principal observing closed for the season.

(15.) After a careful examination of the country I found that, taking the most favourable line, namely that bordering the coast-line and on the parallel of 9° 15′, where advantage of the coast-line sand hills could be taken, I could not reach Rámnád, distant only 64 miles, by less than 16 triangles forming a single series. The addition of three stations made this into a double series, which I propose for observation next season. A number of towers or high masonry pillars with temporary wooden platforms will be necessary.

Rámnád Series approximately laid out on parallel of 9° 15′.

(16.) The party returned to recess at Bangalore on 26th May after a tolerably healthy and successful season's work.

Close of field season.

(17.) The out-turn of field work this season consists of 13 principal stations newly fixed by 20 triangles forming 3 quadrilaterals, a hexagon and two fifths of a pentagon, covering 3,239 square miles and extending the (Great Arc) series, which is now complete, 108 miles to the southward, executed at a cost of Rs. 12-15 (or about 26 shillings) per square mile. A set of star observations for azimuth has been taken as usual, and 51 secondary points and minor stations have been fixed, chiefly within the area of the principal triangles above mentioned; but an area of 1,413 square miles is embraced by the secondary triangles exterior to the main series, besides some 20 high and important hill peaks.

General statement of the field season's work accomplished.

The Rámnád Longitudinal Series has been approximately laid out for a distance of 64 miles by 19 stations forming two quadrilaterals and three hexagons, 6 of the high masonry pillars required for which have been built.

The Mangalore and Paniáni Minor Series has been completed and connected with the Coimbatore Minor Series of 1869-70, by a longitudinal branch, through the Pálghát gap in the Western Ghâts, thus completing a circuit for verification. The length of these series is altogether 212 miles, of which 62 has been done by Mr. Laseron this season. Mr. Mitchell laid out and observed about 120 of it during the two previous seasons, the remaining 30 having been done by myself in March and April 1870.

(18.) The object of this triangulation, was to provide reliable trigonometrical points in a part of the country which had not previously been triangulated and thus fill up the great gap left in previous charts of the old (Col. Lambton's) and recent trigonometrical surveys.

Object of the Malabár Minor Triangulation.

(19.) The field season has been an uneventful one, but the following particulars may be thought worthy of mention:—As was to be expected, on quitting the vicinity of the Western Ghâts for the flat lowlands of the South-East Coast, we met with instances of terrestrial refraction such as we had not seen for some years. The heliotrope signals near the sea shore, in cases when the rays passed too near to the ground, or *grazed* over low vegetation, reminded me of the signals I had seen in Sind and the Panjáb. Sometimes an afternoon heliotrope appeared like a pillar of fire, in height 6 or 8 times its width; and the same signal would in a little while appear as two or more distinct, separate signals, puzzling the observer which or which part to intersect.

(20.) On entering the black soil country, morning mirage was to be seen nearly every day about sunrise, such as I was familiar with in the Indus valley and also in the Kistna and Godavery river deltas, but have seldom seen elsewhere. The more common afternoon, or heat mirage was a matter of daily occurrence.

Mirage common.

(21.) Some of the strangest instances of these phenomena were witnessed and noted on the spot by Mr. Bond, who writes as follows:—

Instance of peculiar mirage.

"I was surprised to see the curious phenomenon of mirage, the apparent unusual elevation and nearness of distant objects with an inverted image suspended in air immediately above them, whole villages appearing thus and also as if built on an island. One very close morning, about 6-30 A. M., in May, on looking out for the heliotrope I expected to see on the tower station (a masonry pillar 19 feet high) about 5½ miles distant to the southward, I noticed a curious sight and called Mr. Belcham's attention to it. The entire pillar was visible with an inverted image of it apparently suspended above, and instead of one heliotrope, five distinct images were seen—one at the top and base of each image of the pillar and one in the space midway between their tops. In a little while the signals became vertically lengthened until they coalesced into a pillar of light. In about half an hour the whole (signal and pillar) had disappeared below the ground horizon some 3 miles off". I anticipate great inconvenience from this source in the future.

Wild jungle folk.

(23.) Mr. Bond had the good fortune to procure an interview with a couple of the wild folk who live in the hill jungles of the Western Ghâts, to the south-west of the Palanei hills, and took the opportunity to observe and note on the spot some of their peculiarities. We had often heard of the existence of some strange dwarfish people who occasionally frequented the jungles near our station of Pémalei, a few miles west of Strivilliputtúr, at the north-west corner of the Tinnevelly district, but none of us, when visiting the Pémalei hills for the purpose of selecting, building or observing at this station, had seen any trace of them, except that whilst observing the final angles we noticed some fires burning at night far off in the distant valleys, commonly stated to be entirely devoid of villages, and civilized inhabitants. When returning afterwards to Pémalei, in order finally to close and deliver over charge of the station to the local officials, Mr. Bond having heard that the wild men of the woods occasionally came to Strivilliputtúr with honey, wax and sandalwood to exchange for cloth, rice, tobacco and betelnut, induced three of the "*Kávalkárs*" or hill watchers, through whom principally this barter is carried on, to attempt to catch a specimen of this strange folk. What follows is Mr. Bond's account :—

Mr. Bond's account of them.

(24.) "Knowing a locality they frequented, whence they could easily steal the remains of food and pots left by the herdsmen, the three Kávalkárs went there to look for them, and on the second day sighted a couple, who at once made off through the jungle for the rocks, with great fleetness and agility, using hands and feet in getting over the latter.

Capture of a couple of them.

(25.) "After a difficult and exciting chase and a very careful search they were again caught sight of, crouching between two rocks, the passage to which was so narrow that it cost their captors a severe scratching to reach them and drag them out one at a time by the legs. They were brought to me in a state of great fear—a man and a woman—as I was descending the hill, and began to cry on being led to my camp at a large village a few miles out in the plains. After some coaxing however, with promises of rice and tobacco, they consented to accompany me willingly. On reaching my tent in the evening I gave the man some clothes, and offered them a little money in small silver and copper coins. Each of them selected the latter, refusing the silver pieces of ten times the value, saying that they could get rice with the copper, and apparently had no idea of the value of the former. I gave the woman some pieces of cloth and a few small things, for which they both shewed their thanks by repeated prostrations on the ground before me.

Their peculiarities noted.

(26.) "The rest of the day was spent in taking notes on this strange pair and in getting from them all the information I could through the hill watchers, who were able to converse with them to a slight extent. They seemed as great a curiosity to the villagers themselves as to myself; and a crowd assembled to watch them, expressing their surprise at the ease and freedom with which they sat in my tent without shewing any fear or any desire to run away. The following observations were noted on the spot :—

Description of the male.

"The man is 4 feet, 6½ inches in height, 26¼ inches round the chest and 18½ inches horizontally round the head over the eyebrows. He has a round head, coarse black, woolly hair and a dark brown skin. The forehead is low and slightly retreating; the lower part of the face projects like the muzzle of a monkey and the mouth, which is small and oval with thick lips, protrudes about an inch beyond his nose; he has short bandy legs, a comparatively long body and arms that extend almost to his knees: the back just above the buttocks is concave, making the stern appear to be much protruded. The hands and fingers are dumpy and always contracted, so that they cannot be made to stretch out quite straight and flat; the palms and fingers are covered with thick skin (more particularly so the tips of the fingers), and the nails are small and imperfect; the feet are broad and thick skinned all over; the hairs of his moustache are of a greyish white, scanty and coarse like bristles and he has no beard.

"The woman is 4 feet 6½ inches in height, 27 inches round the chest (above the breasts) and 19½ horizontally round the head above the brows; the colour of the skin is sallow, or of a nearly yellow tint; the hair is black, long and straight, and the features well formed. There is no difference between her appearance and that of the common women of that part of the country. She is pleasant to look at, well developed and modest.

Description of the female.

(27.) "There are said to be five or six families living about the Pémalei hills, men and women being about the same height, all the men having the same cast of features and being built as the specimen above described.

Number and general appearance.

"The dress of the man consists of a "*langoti*" or small piece of cloth tied round the loins. The women when they cannot procure cloth wear only a skirt of leaves.

Dress.

"They both believe themselves to be 100 years old, but judging from their appearance I suppose the man to be 25 and the woman about 18 years of age. They say that they have been married 4 years, but have had no children.

Age.

"Their marriage custom is very simple; a man and woman who pair off, mutually agree to live together during their life time, the conditions being that the man is to provide food and the woman to cook it, and the marriage is considered to be binding after these conditions have been carried out for the first time, *i.e.* after they have eaten their first food together.

Marriage custom.

(28.) "They eat flesh, but feed chiefly upon roots and honey. The roots, of which the man next morning went to the jungle and fetched me two kinds, are species of wild yam. I tasted both when cooked and found them far from unpalatable.

Food.

"They have no fixed dwelling places but sleep on any convenient spot, generally between two rocks or in caves near which they happen to be benighted. They make a fire and cook what they have collected during the day, and keep the fire burning all night for warmth and to keep away wild animals. They worship certain local divinities of the forest,—Rákas or Rákári, and Pé (after whom the hill is named, Pé-malei).

Dwelling.

"When one of them dies the rest leave the body exposed and avoid the spot for some months. Whenever the herdsmen, wood-cutters or hill watchers come across a corpse and tell the "*grám munsaf*", or head village official, he sends men to bury it and reports the circumstance to the Tahsíldár. The grám munsaf of this place (Mamsápuram and Shiventipatti) told me that six had been buried under his orders.

Neglect of their dead.

(29.) "As I detained this couple in my camp till late in the evening, they begged to remain all night, as they were afraid to enter the jungles so late for fear of wild beasts unless they had a torch with them. I then offered them food if they would cook it near my tent, and gave them what they asked for, rice; but when a fowl and curry stuff were suggested they took them also. The man would have killed the fowl by cutting off its head between two stones, but I told my people to give him a knife and shew him how to cut its throat, which they did, but he evidently disliked to use the knife and begged my servant to do it for him, and turned away his head as if he did not wish to see it done.

Cooking and feeding.

"Whilst the woman cooked the rice, the man cut up the fowl, by placing the knife between his toes and drawing the meat along the edge of it. They seemed ignorant of the use of salt and curry stuff as they did not use the condiments till told to do so. Moreover they wanted to eat the food when only half cooked.

"The man having washed his hands remained squatting on the ground till his wife served him, which she continued to do, without eating anything herself, till he signed to her that he had had enough: she then brought him water to wash his mouth and hands and afterwards ate her own food.

"The fingers alone were used in eating: some rice mixed with the curry was collected into a lump and thrown into the mouth, and I noticed that they did not mix any of the meat with the curry. What remained of their food was put carefully away and carried off next day into the jungle.

(30.) "Next morning I sent the man to fetch specimens of the roots they ordinarily feed on whilst the woman remained at my camp. On his return soon after midday I dismissed them apparently not ill pleased with their involuntary visit."

Dismissal.

(31.) I am happy to report that all my assistants have worked willingly and well, sending in their weekly diaries and their monthly abstracts and returns with regularity. A brief account of the work done by each assistant taken from his own narrative report is given here.

Assistants of the party.

(32.) Mr. G. Belcham, Assistant Surveyor 1st grade, was transferred to this party from No. 1 Extra Party (Astronomical) in order to practise the usual field duties of a triangulating party, of which he had hitherto had little or no actual experience. During the first month of the field season, he remained with me as observatory recorder and office assistant, occasionally using a small theodolite for practice. During the next two months, January and February, he was employed in a reconnaissance of the country along the parallel of 9° 30', with a view to the Rámnád Longitudinal (approximate) Series. He carried out this duty well, undergoing a great deal of exposure and thoroughly examining the country, without however being able to lay out any definite regular series, although he made a general scheme of triangulation, possible at the cost of tracing and clearing nearly all the rays and building high towers. He also, during this time, visited and observed at several points about the island of Rámésweram with a view to the Ceylon connection.

Mr. G. Belcham.

He next took up a little minor triangulation with the 12-inch theodolite for the determination of the position of Pandalagudi, Zenith Distance (Lat.) Station. The results of this, his first essay in independent triangulation, are satisfactory. The rest of the field season (seven weeks) was spent in building two masonry pillar stations, one with solid platform 16 feet high, and the other 19 feet high.

(33.) Mr. J. Bond, 2nd grade Assistant Surveyor, has been temporarily attached to the party, joining my camp on 19th December, when he took up the duties of observatory recorder and office assistant, in performing which, during the ensuing two months, he gave me entire satisfaction. He next undertook the final closing and delivery of 8 of the principal stations, which he accomplished in 5 weeks, marching over 200 miles. He was next engaged, during the last six weeks of the field season, in station-building and ray-clearing on the Rámnád Series, and nearly completed two stations.

Mr J. Bond.

(34.) Mr. C. D. Potter, Assistant Surveyor 2nd grade, has done a good season's work, having built two (23 feet) masonry pillar stations, 4 large platforms, and finally closed and delivered over 4 stations, besides inspecting and repairing or restoring the closing piles, &c., of 9 stations about the Cape Comorin Base-line. He also traced and cleared some 90 miles of rays carrying out my instructions with diligence.

Mr. C. D. Potter.

(35.) Mr. E. W. Laseron, Assistant Surveyor 3rd grade, has been employed throughout the field season in the completion of the Malabár Minor Triangulation. This triangulation was begun by Mr. Mitchell in 1871-72, starting from a side of the principal triangles near Mangalore and has closed at Coimbatore, on the closing side of the Coimbatore Minor Series, a short series which was done by myself with a 14-inch theodolite in March and April 1870, emanating from a side of the Great Arc Series. The total length of this series, between the sides of these two principal series, is about 212 miles. Mr. Laseron's triangulation appears to be as good as could be expected and his portion of the entire work compares favourably with the rest of the work.

Mr. E. W. Laseron.

Extract from the Narrative Report—dated 1st August 1874—of W. G. BEVERLEY, Esq. Officiating Assistant Superintendent 1st Grade, in charge Assam Valley Triangulation.

(2.) The rains having ceased earlier than usual, the party was able to resume field work by the middle of November.

(3.) In order to give time for advancing the approximate work and constructing pillars, I visited Selá and Kurwá principal stations to fix peaks in the Bootan Himalayas and fill up the gap to the west of Long. 92° 30'. The weather was however very unfavourable, and the atmosphere unusually thick for the time of the year, and no distant peaks were observed. The position and height of the obelisk in the river were determined, also the heights of the Church in Gowhatty and of a remarkable temple in the neighbourhood, all of which had been overlooked at the commencement.

(4.) On my way to Nikorí-Chaprí T.S. to commence final observations, I visited the hill stations of Kandalí, Kholá (a station in Nowgong) and Púraparbat in Tezpore, and was able to fix the civil station of Nowgong, the permanent mark being the S.W. corner of the Jail wall. Several new peaks were also added and heights taken to nearly all. A better value was also obtained for the side from which Tezpore Church had been fixed.

(5.) During December and part of January, I took final observations from Madaigáon T.S., Nikorí-Chaprí T.S., Rodongá T.S., Belagurí P.S. and Nigrí Ting T.S. and carried 5 final rays. I also reconnoitred the country about Jorhát, to take steps for fixing it, and then ascended the Brahmaputra up to Dibrúgarh to examine the nature of the country on either bank.

On my return I found the station of Majhulia ready, and I took final observations from it, and from Bor Bhití T.S., Bor-Chaprí No. 2 P.S. and Phakwadol T.S.

(6.) The advance stations not being built I marched to Sibságar on the 18th February, and examined the ground about with a view to fixing points in the civil station and the Revenue Survey permanent mark, either by traverse or triangulation. On returning I visited the selections of Gauriságar, Bor-Alí P.S. and Sintamunigarh T.S. and took up the trial and final rays between them.

(7.) While these were in hand I took secondary observations to peaks, whenever weather permitted, from them. I completed the principal angles remaining at Phakwadol T.S. and one angle at Noe Alí T.S. by the end of March. During April, I completed the principal observations at Noe Alí T.S. and Sintamunigarh T.S. and took secondary observations at Gauriságar Temple S., selected and built Gohaingáon P.S. and observed from it the Revenue Survey station and 3 points in the civil station.

(8.) Sibságar has been fixed by direct triangulation but the values are for the present dependent on a base-line measured in the station. These values will be corrected in the ensuing season, when the principal side Gauriságar to Gohaingáon P.S. has been directly obtained.

(9.) By the 24th April the low ground was all under water from the continuous heavy rain, and I closed work and marched to Dikú Mukh, and left by steamer on the 30th on return to recess quarters.

(10.) Mr. Harris left Shillong on the 20th October, and marched to Gowhatty. He was employed in entertaining Khlassies, masons &c. for his establishment and in looking after repairs of tents &c. during his stay there. He left by steamer on the 8th and arrived at Nigrí Ting on the 14th November, where he commenced work by renewing the scaffolding at that station and sending men and materials across the Brahmaputra river. By the end of December he had completed and built the pillars at Rodongá and Belagurí and the masonry portion of that at Phakwadol.

(11.) Mr. Harris had 3 parties at work. By the end of March he had completed and built all the pillar and post stations that had been allotted to him. His progress was slow, from his inability to visit and superintend the different parties at work owing to repeated attacks of fever and enlargement of the spleen. He was to have selected and built Borghup station, and cleared the ray from Bor-Alí to Gauriságar, but was so prostrated by illness that he was at last unable to undertake any work and had therefore to retire from the field in the beginning of April.

(12.) I had repeatedly desired Mr. Harris to obtain a medical certificate and retire, but he was anxious to push on the work and advance the progress of the Survey, and continued in the field longer than advisable.

(13.) Mr. Harris returned to recess quarters at Shillong on the 24th April. His constitution however was quite impaired, and he suffered from repeated attacks of fever and dysentery, and died on the 12th May. The Department has lost in him a very useful and valuable member.

(14.) Mr. O'Sullivan arrived at Gowhatty on the 30th October and soon after completed all his arrangements for the field. While waiting for the steamer he visited Mairangká principal station to take secondary observations to peaks, but was unable to do any work because of the unfavourable state of the weather.

(15.) Mr. O'Sullivan left on the 8th November and met his establishment at Nigrí Ting on the 15th and commenced work at once. By the end of the month he had cut and cleared 2 final rays, selected a station on the right bank, and taken a large number of horizontal and vertical angles at Nigrí Ting. In December he carried 5 trial and cut 5 final rays, selected 2 stations and took some secondary observations from Belagurí and Rodongá on the Majhili.

(16.) At Belagurí Mr. O'Sullivan tried what is known as a post station, and found it succeed remarkably well. These stations consist of three stout logs buried in the ground, and carefully braced together. They have been used at Belagurí, Majhulia, Bor-Chaprí No. 2, Túramára, Raunápúkrí, Soathol and Bor-Alí, and from the rapidity with which they can be constructed have helped materially to advance the Survey. The stations are denoted by the usual dot and circle engraved on a large rock imbedded in the ground, or on a slab let into a masonry pillar 2½ to 3 feet in diameter, and 1 to 2 feet in height.

(17.) The south flank stations were all selected by Mr. O'Sullivan during the previous season on the left bank of the Brahmaputra. I have visited them all, and am able to state that better selections could not have been made. Mr. O'Sullivan was therefore employed to select stations on the north flank in connection with these. To avoid the frequent crossing of the river and to save time, he was directed to select and build the stations required on the right bank, to carry and cut the trial and final rays, and also to take the principal observations with a 12-inch theodolite.

Mr. O'Sullivan has ably and energetically executed the instructions given him, and the following is his out-turn of work :

Miles of trial and final rays cut	180
No. of stations selected	6
Do. do. built	2
Do. principal angles observed	10
Do. do. stations at which secondary observations were taken	7

(18.) Mr. Hughes commenced work in renewing and repairing the scaffolding and pillars at Madaigáon T.S. and Nikorí Chaprí T.S. He was then employed in building the pillar and scaffolding at Bor Bhiti, and in collecting materials for building at Noe Alí and Phakwadol up to the end of December.

(19.) Mr. Hughes was afterwards employed in carrying and cutting rays for the rest of the season, both on the north and south banks of the Brahmaputra, occasionally under Mr. O'Sullivan, but latterly entirely by himself. He has shown zeal and energy in carrying out his duties, and is becoming a good Surveyor. His out-turn of work during the season comprises—

Miles of trial and final rays cut	48
No. of stations selected	1
Ditto. built	2
In conjunction with Mr. O'Sullivan	
Miles of trial and final rays cut	31
No. of stations built	2

(20.) The triangulation has been carried a direct distance of 46·5 miles; a further advance might have been made had Mr. Harris continued in health. This extent of triangulation is in excess of that of the preceding season, and is due to there having been a good number of stations in advance on one flank. No rays had been carried but the sites were selected after reconnoisance on isolated mounds, old roads and embankments. The rays were carried and cut last field season.

(21.) The country traversed is generally low and subject to inundations. On the north bank, on the Majhuli island, the forest was heavy and the reed jungle very thick, which caused considerable delay in carrying rays through. On the south side the country was more open, large open low grass plains being met with, which very much facilitated ray cutting. These plains are called *Pathars* and are grazing grounds for cattle during the cold weather, being submerged during the rains. Numerous villages also exist both to the north and south of the country over which the triangulation was carried. This tract is one of the healthiest in the Sibságar District. From Noe Alí T.S. to Dibrúgarh, the country again gets very unhealthy from the heavy jungle on both sides of the river, and swamps, for which reason probably scarcely any villages are found except a very long way from the river, and hence the absence of ferries also, between Salmárra Ghát and Dibrúgarh.

(22.) The weather throughout has been somewhat unfavourable. At the commencement of the season, owing to the early cessation of the rains, the atmosphere was very thick and prevented a good view being obtained of the peaks, while the heavy fogs also interfered with the observations being obtained at proper times. At the end of December rain set in, and the season was an unusually wet one.* The ground was thoroughly saturated with moisture, and much inconvenience and sickness resulted from pitching on damp ground. By the 24th April all the low ground was quite under water, in some places to a depth of 3 feet; ray cutting had therefore to be given up and the work closed.

(23.) There was a large percentage of sick in each camp during the past season, but only 2 deaths took place in the field. Every member of the establishment however has suffered more or less from the unhealthiness which prevailed towards the end of the season; several have scarcely yet recovered from the effects.

(24.) Every assistance has been afforded to the Survey party by the Deputy Commissioner of Sibságar; a little inconvenience was experienced from the absence of some Mauzadárs, who were reported to, and dealt with by, the district officers at once.

(25.) In March Captain Samuells the officer in charge of the Revenue Survey party requested me to make a connection with the initial points of his Survey at Jeypore, south-east of Dibrúgarh. The only means of effecting this, was by carrying a Secondary Triangulation along the low hills, starting from the side Sintamunigarh to Gauriságar of the Assam Valley Triangulation. I applied to the Deputy Commissioner for permission, and sent him a rough chart shewing how far into the Lotha Nága territory it would be necessary to penetrate. My letter and chart were submitted to the Chief Commissioner, who desired that every assistance should be given me for the work, and that the District Superintendent of Police should be directed to accompany the party. The reply was however received too late for the work to be undertaken last season; the country at the foot of the hills was represented to be very dangerous from the malaria, and owing to the sickness in the camps, I was unable to get up a party for the work; besides the observations had not advanced sufficiently to give the required data.

* Rain fell on 83 days or nights between 30th December 1873 and 30th April 1874.

Extract from the Narrative Report—dated 1st September 1874—of Captain T. T. CARTER, R.E., Officiating Deputy Superintendent 2nd Grade, in charge of the Brahmaputra Series.

The Native Establishment of the Brahmaputra Series had been ordered to rejoin at Bogra on the 1st of November, and accordingly Mr. Clarke, as senior assistant in the party, was directed to arrive there by that date taking with him Mr. Collins who had just joined the department; I myself arrived at Calcutta on the 1st of November and after taking over charge of the 24-inch Theodolite from the Mathematical Instrument Depôt Calcutta and making other arrangements proceeded on the 4th November to join my camp at Bogra.

By the 10th November the whole party had collected.

Since the previous field season the staff of the party had entirely changed. Mr. A. W. Donnelly, Surveyor 2nd Grade, had succumbed during the recess to an affection of the liver, probably of long standing though doubtless aggravated by the trying work of the previous field season. Mr. C. J. Neuville, Surveyor 2nd Grade, was considered by the medical officer of the department as unfit for work in Lower Bengal and Mr. Healy, Assistant Surveyor 4th Grade, had resigned. Mr. L. H. Clarke, Surveyor 2nd Grade, an officer of long standing in the department and whose services were for disposal on the completion of the Biláspúr Series and Mr. D. Collins, who had just joined the department, were the new staff.

After the usual preliminaries had been settled Mr. Clarke was deputed on the 14th of November to proceed to the tower station of Kánchipára and erect the scaffolding there for the observatory tent, on completion of which he was to proceed to the tower stations of *Káshdoho, Boreil, Narsingbanj, Gobindpur* and *Alangjáni* in turn, clearing the rays to be observed from the same and erecting the bamboo scaffoldings for the observatory tent, and at the same time to fix by traverse any paka buildings or revenue survey marks within a radius of 4 miles round these stations, and failing these, the háts, that is, places where the bazar or rather market is held once or twice a week; these háts have been held in the same places for years, their locality is seldom changed and they are generally the site of some fine old Banyan or other tree which affords protection from heat and rain to buyers and sellers; so that their position when fixed would probably approximate closely to that shown in the revenue survey maps of the district. I had previously addressed the Superintendent of Revenue Surveys, Lower Circle, as to whether there were any revenue survey pillars or other marks which could be connected with the operations of the G. T. Survey in that portion of the Rungpore district through which our line of triangulation lay; a set of survey maps of the Rungpore district on scale of 1 mile to the inch was forwarded but no descriptions of stations were forthcoming; however 23 points, 8 of which were temples and 15 háts or market places as shown on the revenue survey maps were fixed in the vicinity of the tower stations named, and a mark has been left in each hát for future reference, *vide* description of traversed points, season 1873-74.

Having despatched Mr. Clarke on this work on the 14th of November, I left Bogra in company with Mr. Collins on the 17th, arriving at Kánchipára tower station on the 20th: the machan or scaffolding of bamboos, was ready for the observatory tent and the instrument set up on the 24th. It was the 4th of December before observations were completed owing to haze and clouds which continued during the whole of the first week; this combined with a bad form of fever which had carried off two of the heliotropers, prostrated the native doctor, my own servants and several of the men, and in some parts of the Bogra district was almost an epidemic, was not a promising commencement of the field season; besides which the series lay, on its western flank, in the Rungpore district where already the price of rice was high and it was most desirable to expedite the work and complete the series before any real scarcity came on, which was to be anticipated and did occur later in the season. The district of Goálpárá too, in which lay the hill stations on the eastern flank of the series, is none of the healthiest; water is scarce in the hills and the previous year the men employed in building the platform stations had been laid up with fever to a man, though they were clear of the district by the 1st of April; the rays too on the closing side were long, the side Rangira H.S. to Sámding H.S. being over 21 miles, that from Singimári H.S. to Alangjáni T.S. about 20 miles, and the difficulties I had in seeing my signals the previous season with sides never over 12 miles told me what to expect from these long sides when the inhabitants began burning the bamboo jungle on the low Gáro hills about the middle of March, and unless therefore the series was finished early in March there was the chance of its not being completed during this season, as delays of 6 weeks have been known to occur before now in similar ground and for similar reasons. It was therefore a hard and anxious time from the day I began work to the day I finished, the 6th of March, and though the field season was short it was a particularly trying one working as it were against time.

After completing observations at Kánchipára T.S., they were continued at the tower stations as per margin. It was now necessary to cross over into the Goálpárá district and observe from the hill stations, my object being to complete the work there during the months of January and February (the two healthiest) and then cross back again and complete observations at the tower stations on the west flank of the series.

Káshdoho T.S. Dec. 5th to Dec. 11th
Borcil T.S. Dec. 12th to Dec. 19th

The hill stations were taken up and completed in the order as shown in the margin. On the whole the weather was favorable with the exception that from the 4th to the 13th of January, at Rangira H.S., not a single observation was taken owing to a dense haze which was not dispersed till heavy rain fell on the night of the 13th of January. The delay at Singimári was owing to the ray to Alangjáni being obstructed, which was not found out till I proceeded to take observations.

Gáropára H.S. Dec. 20th to Dec. 26th
Peshkárbhita H.S. Dec 27th to Jan. 2nd
Rangira H.S. Jan. 3rd to Jan. 16th
Singimári H.S. Jan. 17th to Feb. 1st
Sámding H.S. Feb. 2nd to Feb. 5th

On completion of observations at Sámding H.S., they were taken up at the tower stations as per margin (an azimuth being observed at Alangjáni T.S.) and on the 6th of March the junction was completed with the Assam Longitudinal Series.

Alangjáni T.S. Feb. 7th to Feb. 19th
Gobindpur T.S. Feb. 20th to Feb. 26th
Narsingbanj T.S. Feb. 27th to Mar. 6th

The result of the connection shows an error of 4·4 inches per mile in the side of junction Alangjáni T.S. to Sámding H.S.: though this is large, yet the elements of Latitude, Longitude and Azimuth, as deduced from both series, approximate very closely, and it does not appear to me that the agreement of the linear value of the common side is a severer test than the agreement of Latitude, Longitude and especially of the Azimuth at the terminal stations.

The positions of the two stations as obtained from each series are as follows:—

			By Brahmaputra Series.	By Assam Longitudinal Series.
Alangjáni	T.S.	Lat.	25° 59′ 7″·817	25° 59′ 7″·618
		Long.	89 48 6 ·629	89 48 6 ·818
		Azmth.	293 0 47 ·700	293 0 46 ·225
		Log. distance in feet,	4·9962011	4·9962313
		Height in feet	96	feet. 102
Sámding	H.S.	Lat.	25° 52′ 42·″990	25° 52′ 42·″801
		Long.	90 4 45· 719	90 4 45· 979
		Azmth.	113 8 4· 608	113 8 3· 161
		Height in feet	368	feet. 367

I will now proceed to report on the work of the assistants attached to the party.

Mr. L. H. Clarke, Surveyor 2nd Grade, completed the building of the bamboo scaffolding for the 6 tower stations on the western flank of the series by the 1st of February; he had also at the same time connected, with a rigorous theodolite and chain traverse, 8 paka buildings and 15 háts or bazars in the vicinity of the same, marking each station of the traverse with two mark bricks and a mound of earth raised above them, the terminal station of each traverse (where it was not a paka building) was subsequently marked by a masonry pillar. Mr. Clarke had also to carry a ray trace between the tower stations of Gobindpur and Narsingbanj T.S. and Alangjáni T.S., and clear the final ray between the same. Subsequently, from the 1st of February till the 2nd of April, he was engaged in the Goálpárá district building the protecting pillars over the hill stations, in accordance with Departmental Order No. 1 of the 15th of January 1866, and also on secondary triangulation.

The secondary triangulation was executed in the first place to lay down points for the Revenue Survey of the Goálpárá district, a narrow strip of which extends from the vicinity of the hill station of Sámding, south between the Gáro Hills and left bank of the Brahmaputra river till it touches the Moymensing district; the survey of this portion of the Goálpárá district as well as the laying down of a definite boundary line between it and the Gáro hills will, I am led to believe, be taken up in the ensuing cold weather, and the points laid down by Mr. Clarke will I hope, be of great service to the officers employed thereon; of these points 11 are at the foot of the hills of which 5 are masonry buildings (3 temples, 1 old indigo factory, and 1 well) and of the others 6 are well known háts, kachahrís, or Police Stations at the foot of the hills, the remaining 14 points are on the lower spurs of the Gáro hills. The stations at the foot of the hills have been marked by paka masonry pillars and from the descriptions given by Mr. Clarke should be easily recognized.

In executing the secondary triangulation a connection was made with the Gáro Hill Survey, executed by Lieutenant Woodthorpe R.E. in the season 1872-73, the stations of Sámding, Rangira, Borchi and Shekarpára being common to both works.

Mr. Clarke's total out-turn of work during the season was as follows and I think deserving of commendation.

No. of miles of theodolite traverse fixing 8 masonry buildings and 15 háts or market places	46
„ „ ray trace traverse and ray clearing	26
„ machans erected at the tower stations for the observatory tent ..	6
„ secondary stations visited	11
„ secondary points fixed	25
„ „ heights „	23
„ hill stations protected in accordance with Departmental Order No. 1 of 1866	5
„ platforms built for secondary stations	20

Mr. Collins, Assistant Surveyor 4th Grade, was appointed to this Department on the 6th of October and consequently was entirely new to the work. He was employed during the whole season as office recorder and in the current duties of the office. There were few opportunities for training him but he was instructed in the use of the 7 inch theodolite and after a short time he was able to compute out observations for time: he gives promise of turning out well with training. I have every reason to be pleased with his application.

It will hardly be necessary for me to enter into the physical aspect, cultivation, natural history &c., of the Gáro Hills, the whole of which have been traversed by Lieutenant Woodthorpe R.E. and fully described by that officer, *vide* the "General Report of the Topographical Surveys of India for the season 1872-73."

The portion of the Rungpore district through which our work lay this year was very populous; being higher than the country described in my last year's report, it was not so much cut up with bhils or swamps and consequently locomotion was easier. The rice crop having failed there was a certain amount of distress on the high land, on the low land the villagers had sown a considerable quantity of wheat as an intermediate crop before the "Aus" or early rice crop would come in June and July; the cases of distress met by myself were chiefly where the person had no means wherewith to buy and whose credit was bad.

In concluding this report I beg to record the assistance rendered by Captain Williamson the Deputy Commissioner of the Gáro Hills.

The health of the party was not good, it suffered a great deal from fever from which 5 men died.

In my last year's report I stated that I had not been able to inspect the tower stations built by Mr. Healy, Surveyor 4th Grade, or the platform stations built by Native Surveyor Narsing Dás, the former's work was very good, and the platform stations and isolated pillars erected by the latter were of very good workmanship, and considering the circumstances under which they were built he deserves much credit.

Extract from the Narrative Report -dated 13th July 1874—of Captain J. HILL, R.E., Officiating Deputy Superintendent 3rd Grade, in Charge Jodhpur Series.

(2.) Lieutenant Rogers having been granted furlough to Europe, I was ordered to Poona to relieve him, and received charge of the party from him there on the 28th October 1873. After opening out the axis of the 24-inch theodolite and cleaning it in my presence, and after giving me full information regarding the manipulation of the instrument, Lieutenant Rogers started for England, and the party proceeded to the field *viâ* Ahmedabad and Palee, and thence across country to Dugur H.S., where I commenced my observations on the 10th December.

(5.) The country from Dugur H.S. northwards, over which the series had to be carried, is a sandy desert. The sand hills are generally flat topped, low, and of about equal altitude, so that the advantages of a hilly country are lost, and short sides are unavoidable. When I commenced my work the weather was good for observing; but unfortunately it did not long remain so; and the season on the whole was, as regards weather, decidedly unfavorable. There was a great deal of cloud and mist, without rain; and except at the commencement of the field season the lamps were almost useless as signals. I closed work on the 3rd April, and during the period of my observations, which was a little less than four months, I find that by adding up the various mornings, afternoons and evenings when work was stopped by bad weather or bad signals, the days so lost amount to the large number of thirty-four. At one station alone I was detained eleven days. Having finished my observations on the date above mentioned, I marched southwards, closing with the help of Messrs. Price and Torrens the stations at which I had worked during the season, and arrived at Mount Aboo on the last day of April.

General Statement of Season's Work.

(6.) The following is a general statement of the season's work:—Observations were taken at 21 Principal Stations, forming 3 hexagons and 2 quadrilaterals, which embrace an area of 1,552 square miles and extend a distance of 90 miles along the meridian. An azimuth was observed at Jambo H.S., in Lat. 27° 16', to two circumpolar stars. The approximate series was extended 102 miles. The positions of the cities of Jodhpúr and Jesalmer, of the towns of Phalaudi and Pokran and of several villages were fixed. The area of secondary and minor triangulation external to the principal series was 1,667 square miles.

Mr. W. C. Price.

(8.) Mr. Price was in charge of the Approximate Series, and extended it well into Bikanír through a very desolate and arid tract. He had very great difficulty in selecting sites for stations and was often obliged to contract the sides of his triangles until they approached the minimum limit allowable. To build towers in such a country, destitute as it is of lime and almost destitute of water and of labour, would swallow up so much money and time that it would only be permissible as a last resource. Mr. Price worked hard and *intelligently*: the amount of his work, especially when the difficulties he had to overcome are considered, is I think very creditable to him.

Mr. C. P. Torrens.

(9.) Mr. Torrens was employed on Minor Triangulation. He has determined the positions of Jodhpúr, Jesalmer, Pokran, and of several villages, temples and other intersected points. He has worked very satisfactorily and energetically and has a good out-turn to show for his season's work.

(10.) It may be as well for me to explain my reasons for directing Mr. Torrens to fix the position of Jesalmer, as that city lies nearer to the future series which will be carried along the meridian of 70° than to the Jodhpúr Series. The position of the town of Pokran which lies in about the latitude of Jesalmer, had to be determined from the Jodhpúr Series. The distance from Pokran westwards to Jesalmer is about the same as from Jesalmer on to the meridian of 70°. The strip of country between Pokran and Jesalmer is exceptionally populous for that part of the desert: it has the advantage of being hilly and adapted for triangulation, and a minor series carried over it would necessarily fix several useful points, and could be conducted without much trouble or expense. On the other hand, from Jesalmer westward to the meridian of 70° there is by all accounts nothing but an uninhabited wilderness of the most desolate kind. Mr. Torrens verified his triangulation by observing an azimuth in the vicinity of Jesalmer.

Mr. W. Oldham.

(11.) Mr. Oldham acted as my recorder and office assistant during the field season, and in both capacities rendered me very efficient assistance. After my observations were completed, and while I was closing stations he made a recorded plane-table traverse of that portion of the Jodhpúr and Jesalmer boundary which crosses the series. The boundary unfortunately is a disputed one, so Mr. Oldham could only carry his traverse along what seemed to him the most probable line in the strip of country claimed by both States. This piece of work will enable me to show an approximate boundary on my Preliminary Chart.

General Observations on the Desert.

(12.) With the exception of the approximate work, which extended into Bikanír, the field operations of the season were confined to the states of Jodhpúr and Jesalmer. In the Jodhpúr desert the triangulation traversed a sandy country, but towards the close of the season the series entered a part of Jesalmer where the ground is hard and strewn with dark shining stones. The reflection from these stones is sometimes like the reflection from water, and for this reason vertical observations to certain of the heliotropes gave a good deal of trouble. Mirage was frequently observable in the mornings; but, except in one or two instances, did not retard my work.

(13.) All over the country triangulated, and especially in Jesalmer, water is scarce and in general brackish. In many cases, according to the statement of the people, well water which is drinkable in the cold season becomes actually poisonous in the hot weather. The villages and wells are few and far between. The former generally consist of a collection of circular thatched wigwams, the inhabitants of which are a primitive, dirty and good-humoured people, given, however, to highway robbery and other forms of thieving. The wells are very deep. I measured one at the village of Akhadna near Nok in Jesalmer (said by the people to be 80 *purush* in depth) which is 5 feet in diameter and 374 feet deep. The water arrived at after such a laborious excavation was unfortunately bitter and quite unfit for use. The deepest well I have seen is at the village of Búkri in Jodhpúr. It has been bored through rock and I found it to be 5 feet 4 inches in diameter, and 450 feet in depth. Its water is good, and I know of no other well so deep in Rajpootana.

(14.) A remarkable thing is that one sees herds of antelope living in districts which are totally without water, except what is drawn from deep wells or village tanks. The people affirm that these animals in common with the rats, which exist in myriads in the sand hills, never drink.

(15.) It is at first strange to come across villages here and there in a wilderness which seems fitted to produce nothing but stunted, thinly-scattered bushes and coarse grass. Wheat has to be imported from Sindh; but near the villages millet (*jawári*), and Indian corn (*bájra*) may sometimes be seen, and in a few favoured localities a little barley. The people also collect a kind of grass (which they call *bhrát*), from which they obtain flour. The grain of this grass is about the size of a pin's head, and is enclosed in a prickly husk which causes a great deal of discomfort to both man and beast, as it sticks in the clothes of the former and the hair of the latter and is very difficult to get rid of. Although most of the villages in the vicinity of the season's operations are sufficiently wretched looking, several seemed to be fairly flourishing and are presided over by substantial Thákurs.

(16.) The town of Phalaudi is an interesting place to come across in such a desert country. The stone tracery of the houses in its principal streets is very beautiful, and it possesses a large and well built fort, the walls of which are over 40 feet high. This fort has a small garrison and its armament consists of a few antiquated field pieces which seemed quite unserviceable from rust and general neglect: in the centre of it there is a deep and capacious reservoir for water. The fort is commanded, but at a distance of 5,600 yards, by the Ekka hill, on which one of my stations is situated. Mr. Torrens has furnished notes (which I append) on the country over which he carried his Minor Triangulation. These notes include notices of the cities of Jodhpúr and Jesalmer and of the town of Pokran.

Phalaudi.

(17.) The natural productions of the part of the desert where my work lay are very few. There are salt works on the boundary between Jodhpúr and Jesalmer near the village of Agar. Near Phalaudi fuller's earth is obtained, and at a place in the same vicinity a natural cement is found which is much prized, and used in the best class of buildings. The chief trade seems to be in sheep and salt. The *banjáras* who bring corn from Sindh load their bullocks for the return journey with salt; they also carry away loads of the fuller's earth just mentioned. The most useful animal in the desert, the camel, here seems to be little if at all in the market. The people breed their own camels and keep them for their own use. Good, serviceable blankets, which are made in every village, also seem to be kept for home use, and are not a general article of sale.

(18.) The desert is very heartily dreaded by the people of the surrounding districts, probably on account of its desolate appearance, the frequency of its famines, and the distress and disease that are generally prevalent among the poorest classes of its inhabitants, owing to the miserable food and unwholesome water on which they are compelled to subsist. Such causes of disease removed, it would seem to be generally very salubrious. A few cases of fever and Guinea worm occurred among the native establishment; but the party, on the whole, enjoyed excellent health. In order, however, to attain this result great care had to be taken to supply the men with good food and water, the latter often having to be brought on camels from very remote wells. The coolness of the weather, which was probably due to the great amount of cloud and mist, may also have contributed to the healthiness of the party.

Health of the Party.

(19.) In conclusion, it only remains for me to acknowledge gratefully the assistance given by the Jodhpúr, Jesalmer and Bikanír Durbars to myself and my assistants. The Jodhpúr and Jesalmer Durbars furnished me with guards of sepoys and sowars, and the former sent an excellent vakeel with me who was of the greatest service to me all through the season. Mr. Price reported to me that every help was given to him in Bikanír, and Mr. Torrens bore testimony to the cordial assistance he received while working in Jesalmer. Without such assistance progress in such a region would have been almost an impossibility; but with it, all trouble was removed except what was inseparable from the work itself.

Conclusion.

Notes by Mr. C. P. Torrens.

The city of Jodhpúr lies at the foot of the hill on which the fort is situated, and at its southern side; the greatest length from north to south is about 2½ miles, and the greatest breadth ¾ of a mile. It is closed in on the north side by the fort, and on the east, south, and west by a high wall, capable of mounting guns, having six gateways. It is a good specimen of a native city and is kept fairly clean; there are many wells, and three tanks, one of the latter, an artificial one (only completed last year) is very fine and large, its bed and sides being of "paká" masonry.

Jodhpúr City and Fort.

The fort is built on a hill, the highest in the neighbourhood, rising 420 feet above the surrounding country. There are two roads leading up to the fort, which unite a few yards distant from the gateway, and turn a sharp corner before reaching the gate; both roads are

well protected by guns; besides this there are two other gates to be passed before the fort is gained, the first a small yet strong one in a narrow pass between two rocks, and the second a large one approached by a steep ascent, well commanded by guns, and like the outer one made difficult by being placed round a corner. Access to the fort from any other direction would be impossible, as the sides are sheer precipices of from two to three hundred feet. The country below is commanded on all sides by the guns of the fort. There is a good sized tank in the fort.

Jesalmer City and Fort.

The city of Jesalmer is much smaller than Jodhpúr, its reported number of inhabitants being 10,000; but from all I could see and hear, the place was once in a far more flourishing state, and the ruins of its former greatness are yet to be seen. The water supply for the city is obtained from an adjoining lake, and when this fails, which is generally the case early in June, good water has to be brought from the small village of Kisan Ghát which is about 3 miles distant. There are numerous wells in the city but the water is not good. The city used to be closed in by a rampart, now useless, as the wall is rapidly crumbling to pieces, and has fallen in in many places.

The fort, once strong, is now in a dilapidated state and would ill stand an assault; it contains no tank but many wells. The Jain temples in the fort are very fine, the carving in stone being exquisite; in fact this may be said of most of the houses in the city, the doors, windows, and walls having more or less carving about them. The greater number of the inhabitants, who reside within the walls of the fort, consist chiefly of a mixture of Bháti Rajpoots and Jains, and are as a rule great opium eaters.

Pokran.

The town of Pokran is on low ground, closed in by hills to the north, south, and west; and high ground to the east. Water is very plentiful in the neighbourhood, and very good; the town possesses three tanks, fine large ones, reported to contain water throughout the year; besides these there are many wells. There is a small fort in the town well built, and strong in appearance; but quite commanded by the adjacent hills.

Close to the town is a large salt marsh about 5 or 6 miles in diameter, into which the drainage of the surrounding hills finds its way during the rains. From the water of this marsh as also from that of another somewhat larger in dimensions, near the village of Lowah (8 miles S.E.) a small quantity of salt is reported to be obtained.

Nature of Country.

The entire tract of country through which the Jesalmer Minor Series passes, with the exception of a few square miles of fairly cultivated ground round Pokran and Jesalmer, is nothing but an arid sand waste, consisting of low sand hills covered with scanty brush-wood. Villages, small and few in number in the eastern portion, get yet smaller and fewer as you proceed west. Vegetation also decreases rapidly, and at 15 or 20 miles west of Pokran, even the *bhrút* grass refuses to grow; its place being taken by a kind of shrub (peculiar to the desert) called by the natives *lona*; the seed of which is collected after the rains and stored away for the year's consumption; it is far inferior to the grain of the *bhrút*, and is very brackish; so much so that it is only eatable after being well washed in fresh water, and even then, only when mixed with twice its quantity of good flour. From the appearance of the grain, and from what I could learn from the natives, there is not much nutriment to be derived from it; and it appears to be used but to increase the quantity of food taken by each individual. Most of the villages have small ponds in which the rain water collects, in a good season sufficient to last for 7 or 8 months, but as a rule, owing to the scanty fall of rain, the supply fails in from 4 to 6 months; the villagers then have to get water from long distances (16 to 18 miles). I have also been informed that some of the poorer classes who cannot afford to get the water from a distance, drink the brackish water (a well or two of which every village possesses) mixing with it a little *dahi* (curds) the acidity of which in a measure counteracts the brackishness of the water. The average depth of wells is about 250 feet, and the water in all more or less brackish, good fresh water having been procurable but twice in the series, at Pokran and Jesalmer.

Extract from the Narrative Report—dated 4th August 1874—of W. C. ROSSENRODE Esq., Deputy Superintendent 3rd Grade, in Charge Eastern Frontier Series.

(2.) In compliance with your request I proceeded to your Head Quarters, after completing the Southern Section of the Bilaspur Meridional Series G. T. Survey of India, with the party attached thereto.

(3.) All the Principal computations of the above series were brought up at your Head Quarters, and a good portion of the Secondary work had been completed when I closed office and left for Burma, to resume the field operations of the Eastern Frontier Series.

(4.) Agreeably to instructions, I left your Head Quarters; and proceeded to Chunar, took charge of all the Government property appertaining to the Sambalpur Series, deposited there, and then started by rail to Calcutta.

(5.) I arranged for the passage of the men and the transport of the Government property by steamer, and sent them under charge of Mr. Henry Beverley. I followed by the next steamer, and on my arrival was informed that cholera had broken out among the Native Establishment, that 2 men had already succumbed, and a third man had been attacked that very morning and was immediately removed into the Rangoon Hospital. He died there that same night. The men were then removed into tents some distance from their former locality, and no fresh cases occurred.

(6.) On arriving at Rangoon I made enquiries for the 10 elephants which were, at your request, to be purchased in the Province, for the use of the party, and heard that they were at Moulmein and that orders had been issued directing them to be sent on to Rangoon to join me. The elephants reached Rangoon on the 17th, and on the 18th November they were made over to me.

(7.) These animals had never been laden. They were shy and timid of strangers, and were accustomed to the Burmese words of command, and could only be controlled by the men of the Province. Acting on the Chief Commissioner's suggestions, I had brought drivers from Upper India for the elephants. These men had no control whatever over the animals; in fact, they could not approach them. The men who had driven them from Moulmein to Rangoon could not be induced to remain a few days with the elephants, until my men became used to the animals and learned the Burmese words of command, which the animals understood and obeyed. I now had no other alternative but to engage Burman mahouts at once. I succeeded in employing two men at 14 rupees each per mensem, and failing to obtain others, I wrote to Colonel Duncan, and he, through the Deputy Commissioner, sent me two others after I had left Rangoon. These men were employed by the Deputy Commissioner on 25 rupees each per mensem, and as these rates were preposterously high, I returned them to Rangoon the day that they arrived, adopting this precaution to avoid any intercourse between my men and them, for fear of the former becoming discontented.

(8.) Being convinced that the new elephants would be useless to me for some months, I applied for and obtained the consent of the General commanding in British Burma, to my being supplied with five Commissariat elephants on hire for a couple of months until the cattle attached to the party became more tractable and were trained to carry loads.

(9.) With the Commissariat elephants and country carts, I was able to leave Rangoon on the 25th November, a week after the newly purchased elephants had joined me from Moulmein. During this week their pads and saddles were made, the former at the Rangoon Jail, and the latter by the elephant attendants. The new elephants carried nothing. For a month or more they were a source of great anxiety to me. They were constantly throwing their drivers and bolting into the forest, and were recaptured at much expense, after long intervals. Two men were severely hurt from falls, one died about a month after, and the other still complains of pains in his back from the injuries he received six months ago.

(10.) The grand trunk road from Rangoon to Prome, the only made road in the Province, brought me to the West End of the Base-line. Here the carts were discharged, as they could not proceed further, owing to the country being still too wet. Carts are used in the interior in the dry weather, only from the middle of January to the end of April. The jungle requires to be cleared annually from the cart-track, and fallen trees, and other obstructions are not removed but avoided by fresh clearances of the jungle: there are no made roads in the interior. The forest is cleared to the extent of 5 or 6 feet in width, the most level country is selected and the carts soon make tracks and wind, turn and twist through this cut path, avoiding ravines, swamps, and all such impediments which wheeled conveyances are unable to surmount. These cart-tracks are made from village to village, and are most circuitous and tiresome.

(11.) I arrived at my first station, the West End of the Base-line, on the 4th December. After inspecting the station and arranging for coolies for Mr. Mitchell, I left him with instructions to reclear the ray to Kedau Pillar Station, and proceeded with Mr. Clancey to the East End Station of the Base-line, arranged for coolies, and started Mr. Clancey on the ray from it to Kedau Pillar Station. I personally took up the two rays from the East End Base to Keingbingyee and Tongtalung Pillar Stations, and commenced the construction of the wooden scaffolding for the observatory tent and the observer at the latter station, as the ray to it approached completion. The next scaffolding I took up was Kedau, and I then proceeded to Keingbingyee, and completed the scaffolding and the ray to that station from the East End and began my final observations on the 1st January 1874.

(12.) Messrs. Mitchell and Clancey after completing their respective rays, took up the ray Kedau to Tongtalung, one at each end. I ordered Mr. Clancey to join me at Keingbingyee

to record in the Observatory, and Mr. Mitchell continued the ray and had it ready when I reached Kedau Pillar Station, after completing my observations at Keingbingyee Station.

(13.) The paddy crop was uncut, the harvest had just commenced when I took up the ray cutting. Coolies were obtained with difficulty, but the coolie contractors, who had worked with me when I was before in Burma, hearing of my arrival, offered their services, and I gladly employed them on the same terms as they were formerly paid on ray clearing. These contractors received 8 annas each per diem for superintending the cutters they had provided, and an additional anna for every man they supplied. I made over one contractor and his men to Mr. Mitchell, another to Mr. Clancey, and retained two others myself. As it was the interest of each contractor to provide as many men as he could, receiving as he did an anna for each man, he supplied the full complement, and no delays occurred in clearing the rays and constructing scaffoldings surrounding the pillar stations. The coolies were paid 8 annas each per diem, and came readily so long as the rays were near their villages; but, although I tried my utmost to induce the contractors to accompany me to the hills, to clear the roads to the stations for conveying the theodolite and for the baggage elephants, I could not tempt them to undertake the cutting of these roads.

(14.) The Burmans are convinced that the block, extending over 40 miles of direct distance, of the Pegu Yoma hills is exceedingly unhealthy. They believe that the men of the plains who work on the hills, are sure to contract fever or lay in the germs of serious diseases. Captain Alexander, the Assistant Commissioner of the Tharrawaddy district, in which I was working, says in his letter to me, dated the 5th December 1873, "I could not send you a man "I could trust on 12 Rs.a month to act as peon, he would only be a common coolie if he did go "into the hills &c. away from his friends and exposed to fever &c. unless he was remunerated "highly.

"I know by experience that in the villages away from the road and east of it, the people "have nothing in the shape of provisions for sale, they only grow and buy sufficient for their "own consumption."

(15.) From the above it will be seen, that Captain Alexander alludes to this unhealthiness, and from the great sickness in camp this season I found it to be the case, for there were a greater number of sick when working on the hills than in the plains.

(16.) Owing to the contractors and their coolies refusing to accompany me, much delay was experienced in cutting the roads to the hill stations for the elephants and theodolite, and especially for the former, which required not only the overhanging branches to be removed, but all overhead up to 15 feet in height to be cut.

(17.) Although the roads were taken in hand early in December, they were not ready when required in February. I and Mr. Clancey had to superintend the road cutters, and to hurry them on, followed by the elephants and baggage. The paths were difficult and very trying to the elephants, but with light loads they got on better than I expected. This hard work of carrying loads up and down hill for 8 and 10 consecutive hours daily, proved the best training school for the new elephants.

(18.) I am dependent entirely on my elephants in this series, and they have to do all the work; it is impossible to obtain the large number of men a survey party requires, to take up the baggage and tents to the hill stations when elephants cannot ascend them, when too steep or rocky. The cattle in such cases are taken as far as they can go, and the property is carried up in driblets by the establishment assisted by the few coolies I may succeed in procuring.

(19.) The elephants of the party have hard work, they are seldom idle, they are either carrying baggage or conveying provisions. The country is devoid of resources, and Surveyors have to exercise their ingenuity and forethought in conducting their operations. To expect assistance, to calculate upon it or to wait for it, ends only in disappointment, disaster and failure. The motto here holds good "every man for himself"; you must do, and be doing; you must work, and have all about you working; you can rely upon no aid or assistance. The free trade and free labor system prevails throughout the Province, and the inhabitants, having the option to work or not, drive the best bargains they can when their services are needed. The Officials are powerless, and recommend the employment of permanent bands of coolies on monthly pay.

(20.) The final operations progressed rapidly during the favorable weather, until the 9th March, when the haze set in and the hills were fired. The atmosphere then became so impregnated with the haze and smoke, that nothing whatever could be seen; even hills 4 and 5 miles distant were entirely obscured. I could not leave the station I was then at until the beginning of May, when partial showers cleared the atmosphere and enabled me to complete the observations. I then proceeded to Myayabeugkyo, where the monsoon broke on us with such violence on the 11th May, that during partial breaks I was able to obtain my angles to the back stations only.

(21.) One of the forward stations, The-ye-khu, was so elevated, about 5,000 feet, that it was generally capped with clouds or was enveloped in mist; the observations to it could not

be taken, as neither day nor night signals were seen continuously for 15 minutes. I was under these circumstances compelled to close work, and return to recess quarters at Moulmein.

(22.) I am glad I did close work, for I found the country daily getting more and more under water, from Shoaygheen to Moulmein. I marched with much inconvenience and difficulty, owing to the whole country being submerged, the depth of water varying from one to four feet, throughout each stage. From the day I closed work to the day the camp reached Moulmein, it rained daily; there were, certainly, breaks for a few hours every day, but for hours together we were never without rain. The signal-men who left their respective stations after me, were able only to rejoin at Moulmein, by engaging boats for the whole distance. Between Pegu and Martaban the country is one extensive swamp for seven months each year. Mr. Beverley found great difficulty in marching last year in the first week of December. He attempted to go across the swamp, but failing to do so retired to the high ground at the foot of the hills and then ascended Kaneindoung and Myayabengkyo Hill Stations, and after selecting The-ye-khu and Kuladong, he found the route he had first taken practicable.

(23.) There was much difficulty this season, about collecting supplies at the different stations, owing to insufficiency of carriage. I had only one spare elephant for this purpose, I have already represented this to you, and I trust you will be pleased to sanction the 4 additional elephants I have applied for. With these 4 and the spare one already alluded to, I shall have 5 elephants for maturing my commissariat arrangements, and I shall be quite independent of the country, where carts are procured with difficulty at exorbitantly high rates; I had to pay 5 rupees a stage for a cart. The demands of the owners of carts must be complied with in this Province, as well as the demands of coolies and guides.

(24.) The season has been unusually sickly. I had an average of 18 sick in camp when I ascended the hills; there were 9 casualties in my camp, and one in Mr. Beverley's, and two men lost their sight. They suffered from ophthalmia, which owing to the intense heat, terminated in total blindness. One was attended by the Hospital Assistant of the party, and the other was sent to the Shoaygheen Hospital, but both cases proving unsuccessful I was obliged to send the men to their respective homes, paying their passage and the passage of a third man to see them safe to their respective villages.

(25.) The work accomplished this season has been the completion of the double figure containing the Base-line. Owing to the long sides and adverse weather, the out-turn has been small, but, I trust I shall be more successful during the ensuing season.

(26.) Mr. Henry Beverley, Surveyor 1st Grade, has been engaged the whole season on approximate work. He had to visit two of the old stations, Kaneindoung and Myayabengkyo; in the former station he found the upper mark and a portion of the pillar destroyed by wild elephants. He excavated the structure until he came upon the lower mark, and rebuilt the pier to its original height and secured it from being again destroyed by wild elephants, by digging a trench round it. At Myayabengkyo he found the pillar and platform totally destroyed: this was done by the Burmans from the plains or by the Karens of the adjoining hills. Every stone was removed and flung to some distance from the station. A large deep pit was dug, with the intention of appropriating the treasure which they suspected was secreted there; finding none, they returned to their villages without being detected. Both Mr. Beverley and I instituted enquiries, no clue however could be obtained regarding the perpetrators of the mischief. A new station was constructed on the debris of the former, and as this station had not been connected with the back stations of the old work, it entailed no revision of angles.

(27.) Mr. Beverley next selected The-ye-khu and Kuladong Hill Stations, forming a quadrilateral, in order to break up the compound figure with several centres which was formerly selected. These new stations entailed the revision of the former work, and owing to bad weather and difficult ground, he did not progress at the rapid rate he usually advances the triangulation. Jungjungia Hill Station situated on a low undulating densely wooded range, extending over a great distance, caused considerable delay: he had to search for the highest spot by erecting several scaffolds on this deceptive undulating ground. His search extended for three weeks of daily labor, until Jungjungia H. S. was selected. The rays then required clearing, which for want of labor and the difficulty of removing the thorny bamboo jungle, interlaced and entwined together, added considerably to the delay. All the rays from the station were successfully cleared, but the one to Sittang proving impracticable after the completion of the ray trace, owing to the undulating hilly ground between the stations being about here and there very nearly the same elevation as the stations themselves. The ray was abandoned, Sittang station rejected, and Kúmbúngán, a station in the plains, fixed by the tedious process of ray tracing, and the rays from it to the connecting stations were cleared, but owing to the rains having set in he was unable to make arrangement for the materials for constructing the pillar, which will require a height of 15 feet.

(28.) In addition to the above, Mr. Beverley selected the stations of Suplitong, Chaiteo, Shoayoungbia, Chaideo and Kathabatong; of these the first three were visited, cleared and constructed in 1869-70, by Messrs. Connor and Bryson. Suplitong H. S. (formerly called

Monthamatong) pillar was dug up by villagers in search of treasure, and as the original site of the station could not be used, owing to the excavation, the new station has been constructed 5 feet from the old spot.

(29.) The pillar of Chaiteo Hill Station was also found to be tampered with; the upper mark-stone was removed, and the pillar partially destroyed by pilgrims, who frequent the pagodas and monasteries on the hill during the annual festivals. This station was rebuilt. Shoayoungbia Pillar was visited and found in good preservation. Chaideo H. S. was selected in lieu of Keylatha, and is on the eastern extremity of the same range. A large pagoda occupies the highest portion of Keylatha hill, and as no suitable site could be found for a station on its summit, Chaideo was substituted. The hill station of Kathabatong was selected and prepared. The following is the out-turn of approximate triangulation:—a quadrilateral, a compound figure and a tetragon; of these the two eastern are proposed stations, and have not been visited. The above figures number 10 stations, selected and prepared over a direct distance of 112 miles. Mr. Beverley's progress has been satisfactory.

(30.) Mr. J. W. Mitchell, Surveyor 4th Grade, joined me at Rangoon on the 6th November 1873, from the Madras Party. He accompanied me from Rangoon to the West End Base-line Station and took up the clearing of the ray from it to Kedau Pillar Station, which he completed on the 15th December. He then began the ray Kedau to Tongtalung. While he was thus engaged, he was taken ill with fever, and was completely prostrated by the severity of the attack; he continued at his post, treating himself, and on regaining health and strength after a fortnight's illness he personally attended to the ray, which during his illness, was continued by the head man of his detachment.

(31.) After completing the clearance of his portion of the ray, from Kedau to Tongtalung Pillar Station, and forming the junction with the remaining portion brought up by Mr. Clancey from the Tongtalung end, he joined my camp at Kedau Station on the 11th January 1874, and after receiving my instructions both written and verbal he left on the 13th January to begin his secondary triangulation, based upon a side of the principal operations to fix the important towns of Rangoon, Pegu and Henzada.

(33.) Mr. Mitchell's secondary series exhibits 11 stations, forming 13 triangles; of which, he has visited 9, the other two are cleared and marked but not visited, he was encamped in the vicinity and owing to weakness and bad state of health at the time, he was unable to ascend them.

(34.) Mr. Mitchell joined me at Moulmein, by steamer from Rangoon; he was still suffering in health. I hope with better health he will be able to shew a larger quantity of work next year after this season's experience in a difficult country.

(35.) Mr. J. C. Clancey, Assistant Surveyor 4th Grade, has been employed clearing rays during the early part of the season. He completed the entire ray from the East End Base-line Station to Kedau Pillar Station, and half the ray from Tongtalung to Kedau, Mr. Mitchell having cut the other half from the Kedau end. After the completion of the above rays, he joined me, and continued the whole season in camp, recording in the observatory and assisting generally in all office duties. He has learned the use of the 7-inch theodolite, and was instructed to observe the sun for time. He has been of great assistance to me in the observatory and office.

(36.) To make himself more efficient for this series, he devoted much of his leisure to acquiring the Burman language, and could read pretty well when he returned to recess quarters; as he is still continuing his studies, he will soon acquire as much knowledge of Burmese as is necessary for communicating personally with the inhabitants in their own language.

(37.) Mr. Clancey afforded satisfaction, and promises to become a valuable assistant.

Extract from the Narrative Report—dated 9th July 1874—of Lieutenant H. J. HARMAN, R.E., Officiating Assistant Superintendent 1st Grade, In charge No. 1 Extra Party.

(1.) The camp and natives of the party left Bangalore for Gúti in the Bellári Division, by march, on October 23rd 1873. Mr. O. V. Norris, Assistant Surveyor 2nd Grade and myself joined the camp on its arrival at Gúti travelling by rail from Bangalore.

Movements of party and its operations.

The main line of levels was opened on November 7th 1873 from a rock *in situ* at Gúti on the Gúti-Bangalore high road; thence the line was carried through Bellári, Hospetta and Hampságram, across the Túngábadra River at Hesarúr to Gadak; then on by way of Behattí and Húblí (near Dhárwar) it was continued to Múndagod in North Kanara, from

which place it was taken due west to Yellápur, and down the Aribail Ghát by the new cart road to the sea at the port of Kárwar, North Kanara District.

This main line was completed on May 10th 1874, and on May 12th tidal observations, for determining the mean sea level at Kárwar approximately, were commenced and were extended over a period of 5 days.

Weather and Health Statement.

(2.) The season was throughout a hot one, for the work; instances of being able to read the staves at greater distances than 4 chains (88 yards) between 9 A. M. and 3·30 P. M. were rare: over the black soil in the Bellári District the weather was reputed unusually warm for that time of the year (Decr. and Jany.)

We experienced many windy days, while working between Bellári and Dhárwar entailing extra labor and loss of time.

From November 7th 1873 to May 1874 work was stopped only on three occasions by rain; between May 1st and 6th we had storms of wind from the N.E. accompanied by torrents of rain; subsequently, and very fortunately, the weather held up fair until May 18th. Down the coast at places south of Kárwar, much rain fell during the month of May.

I am happy to say that the camp suffered but little from sickness during the 7 months it was out on the work; the season in North Kanara was considered a healthy one.

Nature of the country passed over.

(3) For many stretches along the whole line, water was scarce, and this proved very annoying, as the camp had to be pitched in situations, remote from the favorable positions for carrying on the work. The 200 miles of country, from Bellári to Húblí is principally of black (cotton) soil, red soil and rock outcropping on the higher portions.

Black soil is indescribably bad for Levelling work in every way; the red soil gives a good foundation for the instrument, and the air is always much steadier over it than over black soil, but peg driving becomes a troublesome operation.

The above mentioned piece of country is undulating, in places very wavy, and occasionally hilly.

The remaining portion of the line from Húblí to Kárwar was found almost intolerably hilly for the work, as may be seen on reference to the "Sum of Rises and Falls passed over by the Staves" given in the table at the end of this Report; only 14 miles of the main line led across country.

The River Haggri was crossed at Páramadavenhalli, there was little water in it, but its sandy bed stretches from bank to bank over a width of nearly ¾ of a mile.

The River Túngábadra was passed at Hesarúr on February 1st 1874, then it had a width of water of 11 chains, and was 10 feet deep in midstream.

Hours of work and arrangement of the same.

(4.) Work used to be closed between 10 and 10½ A. M. and resumed as soon after 2 P.M. as the state of the air permitted, so that the number of stations observed before and after noon were about equal.

The lengths of line observed in a "Forward" direction (towards Kárwar) balance in amount the lengths of line gone over in a "Back" direction (from Kárwar) in the 20th mile from Kárwar: in the last 20 miles to the sea, the length of the forward section is a little in excess of back section.

Tidal work at Kárwar.

(5.) The temporary Tide Gauge apparatus used at Kárwar consisted of a hollow iron Telegraph Standard, put down at the head of Kárwar pier: the distance of the surface of the water from the zero of the Gauge, was measured by means of a large float, inside the post. Readings were taken at equal intervals of time (solar and lunar, hourly) of a solar and lunar day, extending over 4 complete days: also sets of observations were taken on each side of the High and Low Water. As the rise of tide at Kárwar is small, it is probable that the result obtained by taking the arithmetical mean of the series, observed after this method, will, when corrected by the "mean of the year" be found to be very approximate to the truth.

(7.) The following Tables show the out-turn of work in detail.

	Length in miles.	Number of sections.	Number of stations.	Sum of rises and falls passed over by the staves.
Main Line.				Feet
Double line of levels Gúti to Húblí	200	75	1,962	7,774
Do. do. do. Húblí to Kárwar	104	45	1,930	11,251
Branch lines, also double	19	..	239	845
Totals	323	120	4,131	19,870

The G. T. Stations of Namthabad near Gúti and Kúndgorl near Dhárwar were connected.

The height of top of rails in the Gúti, Gúndakul, Virápur and Bellári Stations on the "North Western Line" of Madras Railway was determined.

Six points of the Kárwar-Bellári Railway Survey were picked up, also 3 points on Irrigation Lines of Levels.

	Number of imbedded B. M. S.	Number of paká points and rocks duly prepared and inscribed.
Gúti to Húbli	13	217
Húbli to Kárwar	3	98
Total	16	315

Mark mounds of stones set in cement were erected in the vicinity of some 50 of the above points.

Extract from the Narrative Report—dated 29th July 1874—of Captain A. PULLAN, S.C., Officiating Deputy Superintendent 3rd Grade, in charge Kattywar Survey Party.

PERSONNEL.

Captain A. Pullan, S. C.
John McGill, Esq., Asst. Supdt.

Surveyors and Asst. Surveyors.

Mr. F. Bell.
„ J. Wood.
„ N. C. Gwynne.
„ T. Rendell.
„ E. Wyatt.
„ W. A. Fielding.
„ H. Corkery.

Head Sub-Surveyor.

Visaji Ragonath.

Sub-Surveyors.

Govindji Mahalay.
Narsu Dinkar.
Krishna Govind.
Shridhar Saccaram.
Vishnu Moreshwar.
Bholaji Bhosekar.
Nilkant Vital.
Keshu Vital.
Tookaram Chowdry.

Apprentices.

Ganesh Ramchandra.
Vishnu Balwant.
Mahadeo Ragonath.

The Party was constituted as per margin. Of the Surveyors Mr. F. Bell joined me in the field during February 1874. Mr. T. Rendell was transferred to the Tidal and Levelling Party from the 1st of March 1874 and Mr. Corkery joined me from Poona on the 6th of December 1873.

Recess work, fair copies.

During the recess of 1873 fair copies of Sheets 10, 11, 20, 21 and 22 were prepared on the 2-inch scale for reduction and publication on the 1-inch scale.

Degree Sheet No. VI.

Degree Sheet No. VI, comprising Sheets 15, 16, 17, 18, 25, 26, 27 and 28 of Kattywar, was fair drawn on the $\frac{1}{4}$ inch scale; this work was commenced by Mr. N. C. Gwynne during recess and completed in the field. The map will be found in my opinion highly creditable to Mr. Gwynne.

Out-turn of Field work.

The out-turn of work during the past field season has been very satisfactory. 2174 square miles of country have been trigonometrically surveyed preparatory to next year's topographical operations, while 2201 square miles of country, exclusive of overlap, have been topographically surveyed and 1234 linear miles of Traverse Survey have been run over that area, demarcating the boundaries of States and checking the details of the Plane Table Survey.

Departure of the Party for the Field.

The Party started for the field on the 22nd October. The subordinate Native Establishment marched from Poona to Bombay, which place they reached on the 27th. On the 28th they sailed by "patimar" (native boat) for Gogo and landed at that port on the 7th and reached Wadwan on the 15th November. With the Native Establishment was the heavy baggage together with the horses of myself and my assistants. The rest of the Party proceeded by rail to Wadwan in Kattywar and I opened office there on the 18th November 1873.

Five or six days were spent in completing the projection of plane tables, mending perambulators, testing chains, &c., and at the end of that time the various plane table and traverse parties dispersed to their different boards. Mr. McGill, Assistant Superintendent,

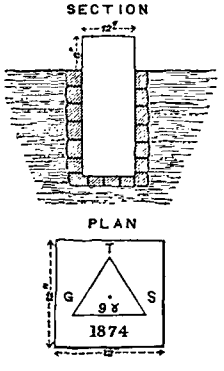
proceeded on the 20th of November to take up the triangulation which I had assigned to him.

Lieut. Gibbs, R.E., Asst. Supdt., Guzerat Party.

He was accompanied by Lieutenant Gibbs, R.E., of the Guzerat Party, as Major Haig was anxious that Lieutenant Gibbs should have the advantage of some weeks' training under an observer of Mr. McGill's skill and experience. Lieutenant Gibbs, remained with Mr. McGill for a month and at the end of that time he proceeded to Wadwan and thence to Sanand to join the Head Quarters of the Guzerat Party at that place.

Captain Pullan.

As I had received instructions from you to make a survey of the city of Rajkot together with the British cantonment, on the scale of 12 inches = 1 mile, I proceeded from Wadwan to Rajkot and took the necessary measures for commencing the survey of Rajkot, examining the ground, ascertaining the position of existing boundary stones, and comparing the map of cantonments as issued by the Quarter Master General's Department with the station as it now stands.



Bench-marks were erected at important points of the Survey. These bench-marks were of stone 12 in. × 12 in. at top, 6 inches of dressed stone appearing above ground and 2 feet being firmly built in below. On the margin is a diagram of one of these bench-marks. The figures below the central dot denote the number of the station in Guzerati.

Besides superintending the progress of this survey and personally examining the projection of the field chart, I surveyed the environs of the town of Rajkot, with the plane table, on our usual topographical scale and also examined, in the field, the work of Native Surveyors Govindji Mahalay, Shridhar Saccaram, Vishnu Moreshwar, Nilkant Vital, and Keshu Vital who were working in adjoining boards. In the month of March I moved northwards, examining the work of the plane table surveyors *en route* to Jhinjura on the border of the Gulf of Kutch. Here finding the "mangrove" swamp and treacherous sand offered considerable obstacles to the plane tabler, I took up L. P. Table, N. W. Section, Sheet 32, myself and surveyed the edge of the gulf accompanied by Ganesh Ramchandra, a very intelligent lad, whom I thus trained to this half land half water surveying, so that next year he will be able to work alone. Besides turning out this plane table I examined the work of surveyors in adjoining boards and continued my inspection until the 25th of April, when the season's work being with the exception of two check traverses completed, I moved in the direction of Wadwan, which place I left on the 6th of May *en route* for Poona, after having seen the field stores and equipment carefully housed for the rainy season.

J. McGill, Esq., Assistant Supdt.

Mr. McGill on leaving my camp at Wadwan on the 20th November proceeded northwards towards the Rann of Kutch to complete the triangulation of Sheet 31, left unfinished by Mr Wyatt, as he found that Mr. Wyatt had in many cases not taken reciprocal vertical angles. Mr. McGill was obliged to visit the major portion of Mr. Wyatt's stations over again. On the 27th of December he was able to proceed and take up the triangulation of Sheets 42, 43, 44, and 45; this triangulation, in many places difficult and irksome, owing to the mud banks and salt creeks which intersected the western half of the work, Mr. McGill successfully completed by the 20th of April, and as he was then quite knocked up by the exposure of the last ten days of work I requested him to proceed to Poona and be ready to open office there on the arrival of those assistants who completed their work first. I may here mention that Mr. McGill fixed the position of the Tide Gauge building at Hanstal and erected a station on the bench-mark west of the building. He also fixed a bench-mark on Somartar Island in the Rann of Kutch. It is unnecessary for me to comment on the work of so able a triangulator as Mr. McGill further than to say that his work is as accurate and good as that of former seasons.

Tide Gauge building at Hanstal.

Mr. F. Bell, Surveyor 3rd Grade.

Mr. Bell was transferred to the Kattywar Party on the 1st of March from the Bombay Tidal and Levelling Party, and proceeded to take up the triangulation of Sheets 40, and 41. Mr. Bell worked very well until the 20th of April, when he wrote to me that the heat was very severe and the refraction and dense haze rendered it almost impossible to observe satisfactorily; whereupon, as the work he was engaged on was not of an urgent nature, I directed him to close work. Mr. Bell requires some practice at supplying points for topographers.

Mr J. Wood, Surveyor 4th Grade. (deceased).

Mr. J. Wood left Poona on the 25th October in charge of the Native Establishment and heavy baggage of the party. He executed this charge successfully and worked steadily through the field season and turned out his plane table in a very neat and workmanlike manner. On the 24th of April he proceeded to Poona, and on the 8th of May I received a telegram from Mr. McGill giving me

the news of Mr. Wood's sudden and violent death. I have already had the honor of communicating with you as to the circumstances of Mr. Wood's sad end; I would here merely record my deep regret for his loss and add my testimony to that of other executive officers as to his steady industry and devotion to his work.

Mr. N. C. Gwynne, Assist. Surveyor 1st Grade.

Mr. Gwynne was employed from the middle of November until the 8th of January in completing the fair drawing of Degree Sheet VI, of Kattywar; this work he did to my thorough satisfaction. On the completion of the Degree Sheet Mr. Gwynne took up topographical work and turned out 3 plane tables in a thoroughly good and artistic style. Mr. Gwynne also trained Ganesh Ramchandra, Sub-Surveyor, and this lad's subsequent work has proved that Mr. Gwynne is a clever and painstaking instructor.

Mr. T. Rendell, Assistant Surveyor 1st Grade.

Mr. Rendell was employed on topographical work until the middle of February and completed 2 accurate and neatly executed plane tables. Mr. Rendell was on the 1st March 1874 transferred to the Tidal and Levelling Party under Captain Baird.

Mr. E. N. Wyatt, Assistant Surveyor 1st Grade.

Mr. Wyatt was employed on topographical work during the entire season and completed 3 plane tables of good quality both for accuracy of detail and artistic drawing. Captain Trotter, R.E., my predecessor, particularly mentioned Mr. Wyatt to me as a very hardworking assistant and I can thoroughly endorse this opinion.

Mr. W. A. Fielding, Assist. Surveyor 2nd Grade.

Mr. Fielding was employed on topographical work during the entire season. He executed 4 plane tables and instructed Sub-Surveyors Vishnu Balwant and Mahadeo Ragonath in the use of the plane table. Mr. Fielding always turns out a considerable amount of work and it is always accurate. He is very painstaking and his style of drawing is now very good.

Mr. W. Oldham, Assistant Surveyor 3rd Grade.

Mr. W. Oldham was transferred to this party on the 1st of June last. He has worked very steadily and well since he joined me.

Mr. H. Corkery, Assistant Surveyor 4th Grade.

Mr. Corkery was appointed to the Department on the 20th November 1873 and joined my camp on the 6th December 1873. As it was necessary that he should be trained, I sent him in the first instance to Mr. Fielding, and afterwards to Mr. Wood, for instruction, and when the latter officer reported him fit for independent work I sent him on the 18th of January to take up R. P. Table, N. W. Section, Sheet 33; Mr. Corkery finished this plane table on the 29th March. He has worked steadily and well, and on the whole his progress has been good.

Sub-Surveyor Visaji Ragonath.

Visaji Ragonath, senior Sub-Surveyor, was employed in projecting plane tables, computing points, and also in the survey of Rajkot on the 12-inch scale; he worked during this season in the same satisfactory way in which he has always done hitherto.

Sub-Surveyor Govindji Mahalay.

Govindji Mahalay worked very well throughout the season executing 3½ plane tables in good style and very correctly. For honesty and energy Govindji Mahalay is a pattern to the rest of the Sub-Surveyors.

* * * * * * * *

Having in view the area triangulated by Mr. McGill, covered as it is by a very large number of well selected intersected points, and the very considerable area of country topographically surveyed, supplemented as it is by the 12-inch survey of the town and cantonments of Rajkot, on which the smallest details are plotted to scale, also having consideration to the small triangular error of the triangles and the inconsiderable chain error of the traverses, I think, I may fairly say that the out-turn of work for season 1873-74 is very creditable to all hands.

Towns.

The principal towns contained in the sheets surveyed this season are as follows.

1st. Rajkot on the bank of the Aji River, the residence of a 2nd class chief and the official capital of the peninsula. The Political Agent for the state of Kattywar resides there and it is also a military station for a small British force. 2nd. Morbi on the banks of the Machu, the principal town of the Morbi State and residence of the Thákur. Under the able superintendence of Mr. Sambu Pershad, the Extra Assistant Political Agent, the town with its well kept roads and neat public offices is an example to the other states. The roads throughout the state of Morbi are in excellent repair. 3rd. Wánkaner the Capital of the state of that name on the bank of the Machu is a strongly fortified town and the residence of the Thákur. Other towns of lesser note are Kotra Sángáni, Pardhari, Lodika, Látipur and Tankaria.

Worthy of mention is the little feudal village of Khirasra standing on a high plateau about 10 miles S.W. of Rajkot: the village is surrounded by a strong bastioned wall, behind which nestle the houses of the "Bhayad"—or blood relations and connections of the Thákur—and over all towers the "Keep" of the Thákur, grim and loopholed; outside the walls and close beneath them are the houses of the cultivators and low caste artisans, these also with a strong wall breast high to protect them.

This village vividly recalls the not very remote times of Surashtra, when every man's hand was against his neighbour, when cattle lifting was the honored occupation, and the popular dictum was that "they may *take* who have the power and they may *keep* who can."

Rivers.

Of the small rivers which water the tract of country surveyed, the principal are the Machu, Aji, Demai and Und. The Machu river, which is the most considerable, rises among the Wánkaner Hills, and flowing under the walls of Wánkaner and Morbi discharges itself into the Rann of Kutch near Mália. This river is remarkable for its rugged and rocky channel and precipitous sides; many a long detour has to be taken along its banks ere a place is found passable for carts.

Aspect of the Country.

Sheet 35, the most southernly portion of the ground surveyed, is hilly, the hills being low steep and bare of vegetation, the valleys between being well cultivated and very fairly productive. This sheet is traversed from east to west by the very peculiar range known as "Sirdhári", which runs for over 30 miles in a long low narrow ridge, varying from 40 to 100 feet in height and from 12 to 8 feet in breadth; no bends or sinuosities occur throughout its length, and it has the appearance of having been "ruled" across the country. The geological formation of the range is basaltic. The ground in sheet 34 is irregular, rising into plateaux with rugged steep sides about 40 or 50 feet high, notably so near Rajkot. The high ground is not however broken up into ridges as in sheet 35. Sheets 33 and 32 are level, the country becoming, as one nears the Rann, an almost unbroken flat, richly cultivated and supplied with water from many large tanks and ponds.

The scenery at the head of the Gulf of Kutch is very peculiar; first, there is the distinctly marked line of cultivation, cotton, wheat, "bajri", making a pleasant variety of color and outline; trees are dotted about, and villages stand out in relief against the sky, or show white against the green masses of the "tope" of trees which almost invariably surrounds them. Next comes the dry, salt impregnated surface of the Rann, half sand half black earth; here and there a stunted bush or two dot the waste, but as a rule it is utterly bare and desolate. A low range of sandy hills shuts in this Rann from the wide spreading swamps, which extend as far as the eye can reach and are covered with a dense thicket of almost impassable mangroves, and intersected with a close network of salt streams. The sea itself is away beyond the mangrove swamps, and at high tides the waters of the gulf roll up, covering the morass and washing up to the very foot of the sandy hills. A white sail dots the horizon here and there, and the observer is cheated for the time into the idea that he is on the sea shore; but a few hours after the illusion is dispelled and the sea might be far away save for the cool salt breeze that pours through the tents, and brings a reminder of the vicinity of the ocean. While surveying the country bordering on the gulf I witnessed some very beautiful effects of "Mirage"; at midday more especially the surface of the soil, glittering with saline particles, seems changed to a glassy sheet of water, the scattered villages assume larger proportions, houses and walls appear gigantic, trees gain double height and bulk, while all appears reflected as in the waters of a placid far stretching lake; but, while the observer gazes in admiration and wonder, the beautiful vision fades, or rather passes on to light up another portion of the coast in like manner. On another occasion the smooth salt surface of the ooze became a still summer sea, such as Vandevelde loved to paint, and on its bosom lay old dismantled boats, white gulls flitted here and there, and a far away grey line of coast closed the picture in the extreme distance. Had I not known that the gulf was six miles off, and hardly accessible at all from land, I should have thought myself within a few minutes walk of the sea, so perfect was the illusion. Nothing grows on these salt morasses except mangrove and a long coarse grass in scattered patches. Various sea birds feed at will, over the slimy ooze and along the edges of the salt streams that wind their way through the swamp; and in the early morning herds of antelope may be seen hurrying back to the borders of the cultivation, after having eaten their day's allowance of salt on the edge of the Rann.

I may notice here the beautiful crystals and agates which abound over the portion of Kattywar which I have visited; masses of crystal white and amethyst together with "fortification" and other agates are scattered broadcast over the ploughed fields or sparkle among the *debris* of the river's bed.

Cultivation.

Cotton is largely cultivated over all this part of Kattywar and is a source of certain income to the cultivators; the principal grains grown are Wheat, "jowari" and "bajri" and near some of the villages are fields of vegetables and patches of sugarcane; wild indigo is found all over this part of Kattywar and I should say might be cultivated with advantage. A noteworthy feature in the country under review are the dense belts of toddy palm which occur at Ságália, Sanosra, Chela, Jodpur and Jodpur Rohisala; there are distilleries at all these places.

Temperature.

The climate of this part of Kattywar is dry and warm away from the sea coast, but as one nears the gulf, is sensibly affected by the cool sea breeze which blows nearly all day. The minimum temperature near Rajkot at 12 o'clock during the month of January, was 66°·9 and maximum at 12 o'clock 89°·0; during February in the same part of the country, minimum 72°·5, maximum 90°·0; during March in the Morbi district, minimum 79°·9, maximum 100°·8; during April at the head of the gulf of Kutch, minimum 87°·6, maximum 103°·0.

Water.

I was agreeably surprised to find that drinkable water is procurable even during summer all along the borders of the Rann. Here and there the Surveyor has to send several miles for good water, but as a rule a little care and arrangement is all that is required to enable the traveller and his people to obtain drinkable water all the year round.

Animals.

A very large number of camels are bred along the borders of the gulf between Juria and Malia; droves of them may be seen wandering here and there over the swamps, browsing on the mangrove; inured from their birth to the treacherous slippery ground, they pass along safely over the ooze and swamp where a Bikaner or Hissar camel would slip and fall before it had gone fifty yards, in fact where any camel but this peculiar breed would refuse to go at all. Great horse breeding country as Kattywar is, not many horses are bred in the part of Kattywar of which I am now speaking. Sheep are very plentiful and their meat is particularly juicy and good.

Population.

The rural population of this part of Kattywar are principally Kolis and Kanbis under the rule of Jhareja Rájputs; a sprinkling of wandering Waghérs along the river banks, and the usual complement of low caste Dhérs to each large village. In the towns there is a large admixture of the Mahomedan element, and along the border of the gulf and in the northern part of Morbi, towards the Rann, many of the villages are inhabited solely by "Miana" Mahomedans, strongly built black bearded fellows, good fishermen and boatmen, but unwilling to work, save for themselves and at their own craft; they have also the reputation of being accomplished thieves.

Proposed arrangements for next season.

I propose that the work of next season shall embrace.

1*st*. The triangulation and topographical survey of the small portion of Kutch required to complete sheets 42 and 31.

2*nd*. The triangulation of the northern half of sheet No. 10_A on the Index Chart.

3*rd*. The triangulation of sheets 52, 53, 58 and 59.

4*th*. The topographical survey of sheets 43, 44, 45 and 31.

5*th*. As there are still many small detached bits of boundary shown *approximately* on the various published sheets of Kattywar, and as these boundaries have now been for the most part definitely settled and marked out, I purpose sending an experienced traverse Surveyor to take them up and survey them correctly; the boundaries when completed will be laid down on the office copies of the different sheets and thus no boundaries will remain approximate on our sheets.

TABULAR STATEMENT OF OUT-TURN OF WORK IN KATTYWAR DURING THE FIELD SEASON 1873-74.

Triangulation.

No.	Observers' Names.	Instrument used.	Area triangulated in square miles.	No. of Points Heights fixed.	No. of Points Position fixed.	No. of stations visited.	Triangles, 3 Angles observed.			Triangles, 2 Angles observed.	
							No. of triangles.	Mean triangular Error.	Discrepancy per mile.	No. of triangles.	Average discrepancy per mile.
								"	Feet		Feet
1	John McGill, Esq.,...	Cooke and Son 7-inch ...	1780	280	650	105	155	10·6	0·6	996	0·9
2	Mr. F. Bell, ...	Troughton & Simms' 6-inch	394	29	108	27	29	11·2	0·6	146	1·0
		Totals, ...	2174	309	758	132	184	Mean 10·9	Mean 0·6	1142	Mean 0·95

Topography.

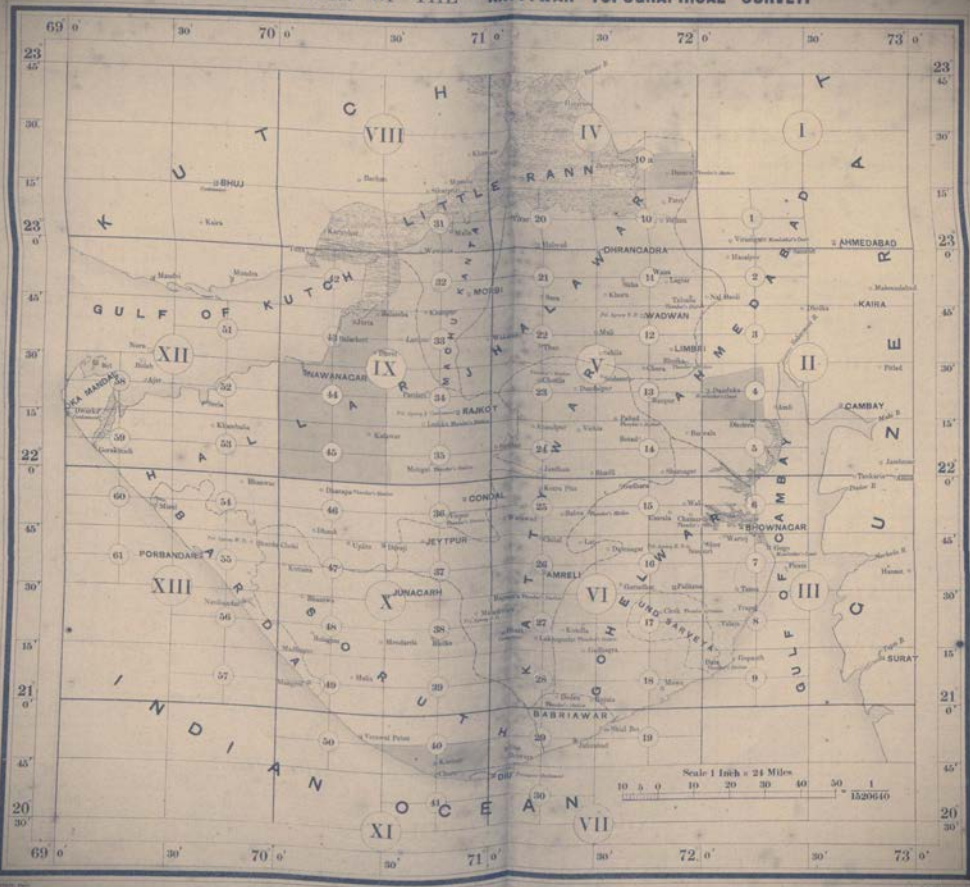
No.	Plane-tabling.	Area surveyed, Scale 2 inches = 1 mile.	Average No. of plane table stations per square mile.	Remarks.
1	Captain A. Pullan, ...	56	5·7	
2	Mr. J. Wood, ...	216	10·2	
3	„ N. C. Gwynne, ...	167	5·7	Empd. for 2 months on Degree Sheet VI
4	„ T. H. Rendell, ...	144	9·0	Transferred from March 1st.
5	„ E. N. Wyatt, ...	226	8·4	
6	„ W. A. Fielding, ...	255	7·0	
7	„ H. Corkery, ...	72	8·6	Joined on 6th December 1873.
	Native Surveyors.			
8	Govindji Mahalay, ...	255	8·9	
9	Sridhar Succaram, ...	242	9·5	
10	Vishnu Moreshwar, ...	220	9·9	
11	Nilkant Vittal, ...	250	10·6	
12	Keseo „	80	8·0	
13	Ganesh Ramchandra,... ...	152	9·4	Very good work for a beginner
14	Vishnu Balwant, ...	8	8·7	
15	Mahadeo Raggoonath, ...	22	9·0	
	Total number of square miles surveyed inclusive of overlap,	2366	...	

Traverses.

Names.	No. of linear miles traversed.		Average error per 1000 links.	Remarks.
	Táluka Boundary.	Check Line.		
Narsu Dinkar	187·2		0·62	Employed for 3 months on the Rajkot Survey.
Krishnaji Govind	202·0	19·8	0·82	Recorder with Mr. Bell from 1st Mar
Bholuji Bhooskar	416·9	22·2	0·59	
Tukaram	236·6	150·3	0·94	
Totals, ...	1042·7	192·3	Mean 0·74	

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

INDEX CHART OF THE **KATTYWAR TOPOGRAPHICAL SURVEY.**



The numerals 1, 2, 3 &c., indicate the sheets on the scale of one inch to the mile. The numerals I, II, III &c., indicate the sheets shown on the Scale of ½ inch to the mile. The one-inch sheets are divided into 4 sections known as the N.E., N.W., S.E., & S.W., sections of the sheets of these 4 Sections will be published on the Scale of the original Survey, viz. 2 inches to the mile for the use of local officials.

Domain country Topographically Surveyed up to 1873-74

Data Transmitted in subsequent up to 1873-74

Photozincographed at the Office of the Superintendent Great Trigonometrical Survey, Pelham Hall, Calcutta 1874.

Extract from the Narrative Report—dated 23rd October 1874—of Major C. T. HAIG, R.E., Deputy Superintendent 2nd Grade, in charge Guzerat Survey Party.

(2.) Owing to rather a large amount of mapping I did not leave my recess quarters at Poona for Guzerat till the 1st December; the party then consisted of the strength as per margin.

Date of taking the field.

PERSONNEL.

Major C. T. Haig, R.E.
Lieut. J. E. Gibbs, R.E.
Mr. A. D'Souza.
" A. D. L. Christie.
" C. H. McAfee.
" E. J. Connor.
" J. Hickie.
" G. D. Cusson.
" A. Bryson.
" G. E. Hall.

Native Surveyors.

Gopal Vishnu.
Ganesh Bapuji 1st.
Raoji Narayen.
Laximon Ghorpuri.
Balwant Govind.
Mukund Diokur.
Ganesh Narayen.
Ganesh Bapuji 2nd.
Bhow Govind
Monajee Aboo.
Trimbak Sadaseo.

Revenue Survey.

Mr. T. A. LeMesurier.

Native Surveyors.

Kuber Parbhudass.
Parbhu Kissor.
Lalu Ambaram.
Jogal Mansukram.
Gopal Ganesh.

At Surat I was joined by Mr. T. A. LeMesurier, Assistant Superintendent Guzerat Revenue Survey, as successor to Mr. A. Dalzell in charge of the Revenue Survey Establishment attached to my party, the latter gentleman having been transferred to the Nassick Revenue Survey.

(3.) On the 16th March 1874 Mr. McAfee left my Party and proceeded to join the Kumaon and Garhwal Party and from the 1st of March 1874 till the end of the field season Mr. Cusson was absent sick.

(4.) During the season one sheet and a quarter, *i.e.* about 690 square miles, have been topographically surveyed on the scale of 4 inches to the mile. Two sheets have been prepared for topography, by triangulation and traversing, connecting all the village trijunctions and other important points on the Revenue Survey Maps with our triangulation. Two sheets, of which the triangulation had been previously done, were completed as above with traversing and one sheet was covered with a net-work of triangles without any traversing and also the triangulation for the Survey of the Dáng Forests in sheets 52, 53, was commenced by Lieutenant Gibbs, who covered an area of about 500 square miles with triangles of 10 mile sides besides fixing a number of intermediate points which can be made stations of a triangulation of smaller sides.

Work done.

(5.) The area topographically surveyed is much smaller than usual, and smaller than I had hoped to have completed; but as it was our first season of working on the 4-inch scale it cannot be considered unsatisfactory, especially as it throws on the hands of the party a larger amount of mapping than they have hitherto been able to attempt in one recess.

Topography.

(6.) I proceeded direct from Poona to Ahmedabad and thence I marched with my whole staff of topographers to Moria, a convenient village about 13 miles on the road to Gogo, and in plane table No. 16 of sheet 80. On this plane table we commenced work, all the Surveyors being for a time spectators, so that they might, when they separated, all work on the same system, which was somewhat different from that to which they had been accustomed; and they then distributed themselves over the 12 easternmost plane tables of sheet 80 so as to be all near at hand, and I visited them all to see that they understood the plan of working.

The start.

(7.) I will now describe in detail the mode of working which was finally adopted and which all the Surveyors now quite understand, though we took some little time in maturing it, during which the work progressed rather slowly.

Mode of procedure.

(8.) I have stated in my last year's report that in designing the project of the traversing, the end I kept in view was to determine the position of a point close to every village site and the positions of all the village boundary trijunctions. Besides these obligatory points the traverses of course give us others, as for instance the traverse stations between the obligatory points and many crossings of roads and nallas. Additional measurements when necessary are also taken to enable all the obligatory points and all the traverse stations to be plotted on the Revenue Survey village maps.

(9.) On distributing the topographers I provide each with a plane table on which is a graticule $3\frac{3}{4}$ minutes longitude by $3\frac{3}{4}$ minutes latitude, and all the triangulation and traversing stations and data points, and along with this a copy of the Revenue Survey Map of every village (wholly or partly included within the graticule) reduced on semitransparent paper to the scale of 4 inches to a mile. On these village maps are also marked all the triangulation and traverse data points.

(10.) A Surveyor thus provided, having made all his points on the ground conspicuous with poles and brushes, where necessary, sets up his table at the given point near some village site from which he traverses round the village with his plane table and lays down the actual

limits of the ground occupied by houses and the emanations of all roads; then if the village is a small one he sets up his table at one of the data points on the boundary and traverses round the boundary, laying down all points where roads cross it; he then has two points on each principal road, one at the village and the other at the boundary, and with the aid of a piece of black leaded transfer paper he traces in the road on to his plane table from the village map. If the distance between the village site and the boundary exceeds three quarters of a mile he traverses round an intermediate circuit, and such of his plane table stations as are important as being near to roads or other topographical features he plots on the village map (by means of measurements to the nearest corners of fields) as well as plotting them on his plane table. He also sets up his plane table at every tank and works along the banks of all streams, such items not being shewn on the village map with much accuracy of detail but merely as non-assessed spaces. In the course of this procedure he will notice any roads which may have recently sprung up and are not shewn on the village maps, and he sketches in the undulations of the ground, and indicates its character whether wooded or open. From the village authorities he borrows the local copy of the village map on which all the hedges are shewn, and ascertains how much of the land is assigned or "Wánta" as it is termed, and who the assignee or Wántawála is, and what portions are lying waste; and this information he indicates on his own copy of the village map.

(11.) Then when he sends his plane table to my Office completed and accompanied by the village maps I have not merely a topographical survey of the country on the scale of 4 inches to a mile, but I have the means of laying down on it all the fiscal details shewing which parts are hedge-bound and which open. The village maps also give the positions of all the wells and the names of all the tanks.—I say I have the means of laying down these minutiæ, but it still requires a little method to accomplish, because if the village map be superposed in its place on the plane table it will not always fit into its correct limits; in fact we may say that if we take any two points in the village map and place them on their correct positions on the plane table we shall find a discrepancy between any third point and its correct position; but if the three points are not far from each other, say $\frac{3}{4}$ of a mile apart, the discrepancy will be so small that it can readily be adjusted by an ordinary draftsman and the necessary correction applied to the intermediate detail. But from what I have just stated, in regard to the process of working in the field, it will be at once understood that, what with triangulation stations, traverse stations and plane table stations, there will be a net-work of points common to both maps by which they can be divided up into triangles always having sides less than three quarters of a mile. Thus by taking a triangle at a time the fiscal details of the village map are easily transferred to the plane table map, and in this way we have a topographical map on which the lands of every village have assigned to them their correct limits and the interior fiscal details being added it becomes a cadastral map of the country. Of course properly speaking a cadastral map is one which shews all the buildings in the towns to scale, but all that I have been able to do in that direction has been to survey the principal thoroughfares through the villages and fill in the spaces with conventional blocks of buildings.

(12.) I must now state in what particulars we in practice deviated from the above detailed method. In the first place during the execution of the first 12 plane tables I directed the Surveyors to transfer the fiscal details from the village maps, each on to his own plane table, as he progressed with his topography. This was found by some hands a very difficult and tedious job, and some of them executed the job in such a way that it had to be done over again; consequently I directed them only to furnish me with the *means* of transferring the details from the village maps to the plane tables in my office.

Deviations in practice.

(13.) Then as I had no separate staff of draftsmen in my Office I had to let the work of transference of fiscal details from the village maps to the plane tables stand over till we returned to Poona, when I found it more advantageous not to transfer these details on to the original plane tables at all, but on to the fair copies, and for the following reasons.

(14.) Before returning to Poona I represented to Colonel Prescott, Superintendent Guzerat Revenue Survey and Assessment, that it would greatly accelerate the publication of the large scale maps if I had the original plane table maps photozincographed in pairs in blue, and so save the labor of having them all traced by hand with the aid of a tracing glass, and I also represented that my contingent grant would not admit of my paying for this at the ordinary rates, and I therefore asked him to apply for permission to have this work regarded as part of the legitimate assistance that should be rendered by the Revenue Survey in the utilization of their maps and charged to the account of the Revenue Survey. This was at once acceded to. Then the Officer in charge of the Photozinco. Office asked me to let him undertake the job as speedily as possible as he then had but little work in hand but expected soon to have his hands full. I therefore sent him the plane tables as they were, without waiting to transfer the fiscal details on to them.

(15.) But to return. The topography of sheet 80 was not completed until nearly the end of March, after which I moved into the Surat District and took up a portion of sheet 14. I was anxious to take up

Progress of topography in sheets 80 and 14.

a portion of this district because in sheet 80 the Revenue Survey detail with which we had to deal was the result of operations undertaken nearly a quarter of a century ago, whereas the detail in sheet 14 is the result of very recent work, and, as might have been expected, the forcing which was necessary in sheet 80 to get the details into their proper relative position almost entirely disappears in sheet 14.

Description of sheet 80.

(16.) The country along the eastern margin of sheet 80 and extending a few miles into the sheet is thickly wooded and closely hedge-bound; but as we advanced west we got into a very open and bare looking country, the trees and hedges being almost entirely confined to the village sites or their immediate vicinity. This sheet includes a very remarkable lake called the Nal (popularly spelt Null) covering an area of about 18 square miles. The water I believe nowhere exceeds 10 feet in depth and for the most part it is capable of being crossed by wading; during the monsoon the depth of water increases and I am told there is then a water connection between the Gulf of Cambay and the Rann of Kutch *vid* this Nal. The water of the Nal is sweet during the monsoon and early cold weather but as the hot weather advances it becomes more and more brackish.

(17.) There are a number of islands in the Nal near its margin. Most of these, and many parts of the banks of the Nal, are covered thickly with reeds which are used by the natives for thatching their houses, and the poorer classes live on the roots, which they clean, dry and grind into flour called "Bír": on the adjoining tracts of salt waste there is a short kind of grass the root of which is also eaten by the natives.

(18.) The country in the east half of the sheet is very level and wooded; the western portion is open, and from the low level many plateaux rise from 5 to 15 feet, to which the cultivation is mostly confined.

(19.) The sheet comprises portions of the Sanand, Dholka, and Viramgam Tálukás of the Ahmedabad Collectorate and small portions of petty states under the Kattywar Political Agency. It is traversed by the Ahmedabad and Gogo and the Ahmedabad and Viramgam roads.

(20.) In sheet 80 there are four different kinds of tenure under which the land is held, *viz.* Khálsa or Senja, Tálukdári, Inámi, and Foreign territory under the jurisdiction of the Political Agent in Kattywar. There is an interesting and lucid explanation of the different land tenures under British rule in Guzerat in the General Report on the Administration of the Bombay Presidency for the year 1872-1873. Here it is sufficient to state that in the Khálsa villages the ryot or tenant of each field pays his rent direct to the British Government; in the Tálukdári villages a Tálukdár pays a rent for the whole village; while in the Inámi villages no rent is paid at all to Government. It is necessary to mention this because of the consequent difference in the village maps. In the map of a Khálsa village we find the land divided into a host of fields, sometimes almost too small to be properly shewn on the 4-inch scale, but of course sometimes as large as 10 or 12 acres, and every tank or unassessed space is indicated. A Tálukdári village map presents very little partition into fields, the roads forming frequently almost the only division of the map and often they are not all shewn nor are all the tanks. Of the Inámi villages generally there are no maps forthcoming at all, but sometimes a map exists giving merely the periphery or boundary of the village. There are no maps at all of the villages in Foreign territory. The Khálsa village maps are therefore by far the most valuable to us and next to them the Tálukdári.

(21.) Khálsa villages are also very frequently divided into Wánta (a share) and Talpat (the remainder), the Wánta land being held by some Tálukdár; but the British Government let out the fields, collect the rents, and settle the account with the Tálukdárs. I mention this, not that there is any difference in the map from that of a village not so divided, but because it is an important division, and one that I am therefore indicating on our final maps.

Description of sheet 14.

(22.) The S. E. section of sheet 14 which was also surveyed during the past season comprises a portion of the Ulpár (spelt also Ulphár and Orpád) Táluká of the Surat Collectorate, and of the Káthor Pargana of the Nowsaree Máhal in Gaikwári Territory. It is a flat country, fairly wooded, but the trees are for the most part small, babool trees predominating. The principal towns in this section are Ulpár, Káthor, Sándhir and Variao. The river Tapti enters this section at the S. E. corner and passes close along its southern margin; in the vicinity of the Tapti there are many ravines 50 feet deep and more, several of which are utilized as roads. The B. B. and C. I. Railway also crosses this section, entering it at about 170 miles from Bombay and leaving it in the 180th mile. There are also several made roads traversing this section, *viz.* the Surat and Dándi road (Dándi is the village on the coast from which the mail boat crosses the Gulf of Cambay to Gogo), the road from Surat to Ulpár and on to Hánsot in the Broach Collectorate in sheet 13 (published), and the road from Ulpár to the Sayen (Sion) Railway Station.

Comparison between the materials of the Revenue Survey in sheet 80 and in sheet 14.

(23.) The villages in this part of the country are much more numerous than in the Ahmedabad District; there the areas of some of the village lands exceed 10 square miles, here one square mile is a common area for a village, and the holdings are small in proportion. There is also an absence of Tálukdári villages in the Surat

District, and only very few Inámi villages, so that sheets 80 and 14 present the extremes of the gain to be derived from the Revenue Survey Maps, and while even in the Ahmedabad District we may obtain a very satisfactory map on the 4-inch scale, shewing all the holdings, bye-roads, foot-paths, wells &c., in sheet 14 it would be quite possible to produce as satisfactory a map on the 8-inch scale, if it were necessary.

(24.) The right plane tables in sheet 14 were completed about the end of April, and I opened Office in Poona on the 1st May.

Close of the field season.

(25.) I will now proceed to report in detail on the work performed by each of my assistants. As it was imperative that I should myself attend to the topography at the opening of the field season, it was impossible for me to ground Lieutenant Gibbs in the departmental method of triangulation, so I directed him to accompany Mr. McGill, Assistant Superintendent in the Kattywar Party, who left Poona on the 7th November. After keeping with him until he had acquired the knowledge of the practical details of triangulation that was necessary, he re-joined me near Sanand near the end of December, and on the 7th January he left with a party to run a longitudinal series of triangles across the middle of degree Sheet II, emanating from side Warsora-Dhámanwa of the Aboo Meridional Series and to close on the Kattywar net-work triangulation.

Assistants.

Lieutenant Gibbs.

(26.) This turned out to be a work of great difficulty on account of the flatness of the country and the denseness of the forest, so that Lieutenant Gibbs had not even completed one triangle before I had to call him away to commence the triangulation of the Dángs, which was a work of first importance but which could not be taken up till the end of February, on account of the deadly fever which closes the Dáng jungles to strangers throughout the cold weather.

(27.) Had I anticipated the difficulties with which Lieutenant Gibbs met in degree sheet II, I would have reserved that work for my most experienced triangulator who perhaps might have achieved a little more success; but it gave Lieutenant Gibbs an opportunity of seeing some of the greatest difficulties with which a trigonometrical surveyor has to contend, and it was owing to no want of energy on his part that greater success was not achieved.

(28.) His initial side Warsora-Dhámanwa lay through a dense jungle which, in the 22 years since the ray was cleared and observed by Lieutenant Rivers, had grown up so as not to leave a trace of its having ever been cleared.

(29.) After several ineffectual attempts to select a couple of stations by mounting high trees, Lieutenant Gibbs was obliged to proceed to fix his stations by means of ray trace triangulation, and he had run a chain of 23 such triangles, of sides varying between ½ a mile and 3½ miles and extending over a distance of about 16 miles, when on the 19th February he had to close his work and proceed to take up the Dáng triangulation.

(31.) On the side Pilwa-Ghontwál he laid out and observed a double series of triangles closing on Rúpgarh h.s., using a 10-inch theodolite by Troughton and Simms and observing his angles on one pair of zeros. A reference to the tabular statement of the out-turn of work will shew how successful Lieutenant Gibbs was in point of accuracy in this work. In this series he fixed 8 new stations and 32 intersected points. These latter are all on hill tops; he tried to fix points in the valleys but did not succeed, on account of the thick state of the atmosphere which rendered the observations of opaque objects backed by trees impossible.

(32.) Lieutenant Gibbs anticipates that there will be great difficulty in the topographical survey of this district, for not only does the haze and smoke impede the view down from the hill tops into the ravines, but the ravines themselves are so precipitous and tortuous that it will be very difficult to find spots in them from which the hill stations will be visible, and the amount of iron in the rocks will render the magnetic compass useless. I attach a very interesting report by Lieutenant Gibbs on this district.

(33.) Lieutenant Gibbs, after completing this work, determined the position of the new Light House on "the Prongs," a shoal of rocks in continuation of the Kolaba promontory in Bombay.

(34.) Mr. D'Souza was employed early in the season in instructing new hands in plane tabling and afterwards in supervising and examining the work of the native Surveyors, and I found him so useful in this work that I contemplate employing him in a similar way next season. He instructed two native Surveyors, Monajee Aboo and Trimbak Sudaseo, in the use of the plane table, in the course of which he with his own hands completed one plane table and nearly half of two others or about 44 square miles on the 4-inch scale. Mr. D'Souza had under him 5 plane table parties, each in charge of a native Surveyor, and he exercised a rigorous supervision over them all, examining each plane table on the ground. The total area of the plane tables which he examined amounts to 360 square miles.

Mr. D'Souza.

(35.) Mr. Christie started on his work from Broach on the 15th November and in the course of the season covered sheet 31 with a net-work of triangles averaging 2 to 3 miles sides, which he executed with a

Mr. Christie.

6-inch theodolite by Troughton and Simms.

(37.) Sheet 31 comprises about 140 square miles of the Broach Collectorate and the remainder is Gaikwári territory. Mr. Christie took pains to connect all his stations in British territory with the Revenue Survey "Bánds" at the corners of the fields in which they were situated. This completed the triangulation of the Broach Collectorate; the traversing which is still required to connect all the village sites and trijunctions will be taken up by the Revenue Survey Party under Mr. LeMesurier next month. Mr. Christie progressed much more rapidly over the western half of the sheet than over the eastern, as the former is open the latter very woody, but he very satisfactorily covered the sheet with points.

Mr. McAfee.

(38.) Mr. McAfee instructed Mr. Bryson and Ganesh Narayen in the use of the plane table and exercised a supervision over Raoji Narayen when working on his first plane table, and afterwards completed one whole plane table and half of another and a portion of a third which he had to give up on being ordered to join the Kumaon and Garhwal Party.

Mr. Connor.

(39.) Mr. Connor, assisted by native Surveyors Gopal Vishnu, Ganesh Bapuji 1st and Ganesh Bapuji 2nd, prepared sheets 78, 79 for topography with triangulation and traversing. Mr. Connor himself executed the triangulation and gave the necessary instructions to his three native Surveyors—each of whom was provided with a traversing party for the running of traverses starting from and closing on his triangulation stations. Mr. Connor did not cover these two sheets with a net-work of triangles but ran a circuit of triangulation round the margin of the two-sheet-space and ran a meridional chain across the centre of the space, and so gave out the traverses as to fix the positions of the sites of all the villages and of the trijunctions of all British village boundaries as well as of conspicuous trees and other points useful to the plane-table Surveyors. There is in these two sheets a considerable portion of Gaikwári territory in which the village boundaries not being demarcated, the traverse Surveyors fixed the village sites and a sufficiency of useful points for plane tabling.

Mr. Hickie.

(40.) Mr. Hickie was employed the entire season in my Office, chiefly in projecting plane tables and charting and miscellaneous current work of which there was an unusual amount, so much so that his hands were always full as well as those of the two native surveyors I also kept in my Office.

Mr. Cusson.

(41.) Mr. Cusson was employed in plane tabling and he altogether turned out 53 square miles very neatly; illness compelled him to abandon his plane table on the 20th February, and he came to my camp where I employed him in my Office until 1st March, when it became apparent that he would not be fit for hard work for some time and therefore for the remainder of the field season he went on privilege leave.

Mr. Bryson.

(42.) Mr. A. Bryson was employed all the season in plane tabling. Having always before been engaged in triangulation, I placed him under Mr. McAfee for instruction for a short time. His draftsmanship was not good, and I am sorry to say he did not inspire me with much confidence as to the accuracy of his work as I had to reject one of his plane tables.

Mr. Hall.

(43.) Mr. Hall was also employed the whole season in plane tabling, and I am well pleased with his diligence and accuracy, it was only his second field season but he has now become a valuable assistant.

Tabular Statement.

(44.) The tabular statement appended to this report will shew in detail the amount and relative value of work turned out by each of my Assistants and by the native Surveyors.

Revenue Survey Establishment under Mr. LeMesurier.

(45.) I have now to mention the Revenue Survey Establishment under Mr. T. A. LeMesurier; he joined me at Surat on the 3rd December and at once proceeded with me to Ahmedabad, and after receiving his instructions he took his Establishment into sheet 82 the traversing of which he took up, connecting every village site and trijunction with the triangulation. He finished this about the middle of January, and then took his Establishment into sheet 14 and completed the traversing in the northern portion of the sheet which it had not been possible to finish during the previous season, and then he took up the traversing of sheet 15 which he finished about the middle of April and then proceeded to Poona.

(47.) During the past recess Mr. LeMesurier, who is a very good draftsman, has been rendering valuable assistance in the drawing of the maps; six sections (double elephant sheets) have been drawn by him. His Surveyors were employed during the first part of the recess in the reduction of their traverses in sheets 82, 14, 15, computing the rectangular co-ordinates of the stations with reference to the centres of the respective sheets, and afterwards in transferring the field details from the Revenue Survey village maps to the blue photozincographs of the plane table sections. These blue photozincographs are furnished me in duplicate; on one copy the native Surveyors transfer the field details in bold black lines, the other is taken up as the final map for submission to your Office, and on it the field details are traced with the aid of

a tracing glass from the first copy.

(48.) In a few days I hope to be able to send you some of the sections of sheet 80 for publication, when I have no doubt you will be thoroughly satisfied as to the advisability of completing the Survey of British Guzerat on the 4-inch scale. We are not in full working trim, yet but I expect that with but very little more assistance (in the shape of an increased grant for contingent expenditure), besides what has been already given me in the Revenue Survey Establishment under Mr. LeMesurier, to be able to turn out annually nearly as much work on the 4-inch scale as was expected from us on the 2-inch scale.

(49.) I should perhaps here mention that the scale of Survey being the same as that of the published maps, and the large scale of 4 inches requiring a softer general tone than maps on the 1-inch scale, my draftsmen have been required to draw in a style altogether different from that to which they have hitherto been accustomed. The drawing of the maps on the 2-inch scale for reduction by photography to the 1-inch scale had to be coarse and bold, whereas in the maps I am now preparing every thing has to be drawn as finely as possible. Doubtless it will be noticed that there is room for improvement in the maps but I cannot but think that considering that they are the first of the kind produced in this Office they must be considered very satisfactory.

Notes on the portion of the Dángs visited in March—May 1874 *by Lieutenant J. E. Gibbs, R.E.*

(1.) The portion of country, to which my report refers, comprises parts of the Dharampur, Bánsda, Baroda and Sulgána native states, and of the Dángs which are for the present under the charge of the Collector of Khandeish.

(2.) The general aspect of the country is a mass of wooded hills and valleys.

(3.) The hills are for the most part isolated, rugged and steep. Towards the east however they become more and more connected, plateaux being formed, which are again sometimes surrounded by higher masses. In the line of the Ghâts, to the east and south of the Dángs, huge and fantastic masses of rock tower above the rest. The spurs of the hills almost invariably rise in steps, and the summits are generally flat.

Hills.

(4.) The valleys till they reach the open country are narrow and very winding, with steep sides, countless short steep ravines running into them down the hills. The beds of the streams are rocky, and the streams are during the dry season naturally bunded up in many places, without which provision the water supply would soon run short. During the rainy season they become torrents.

Valleys.

(5.) The water of the streams is very bad for drinking purposes, as is often the case in thick jungles; but here the inhabitants make matters worse by throwing in poisonous bark to stupify the fish, which then rise to the top, and are shot with arrows if large, or caught in the men's clothing if small. The people in consequence always take care to drink from springs, or from excavations at the sides of the river beds. Towards the end of the hot weather most of the water gets putrid. There is a deep well with good water at Wagai, and another at Gárví. At Rúpgarh there is a perennial spring at the top of the hill, supplying a tank in the old fort and a hollow in a cleft in the northern scarp, with water which is at any rate better than what is obtainable at the foot of the hill. At a few other places the water was palatable, but in most varied from the nasty to the nauseous. At Unáe Mátá there is a celebrated hot spring, which according to my informants cools sufficiently once in 15 days for people to bathe in it; Captain McRae tells me that it is cool only on one day in the year, during the annual fair. When I visited it the temperature was 128¼° F. that of the air in the shade being 89°; an analysis of some of the water I brought away with me gives however nothing abnormal in its composition. It would be interesting to detect the means by which the priests divert the hot water on bathing days before it emerges from the shrine.

Water.

(6.) The slight amount of information as yet collected about this hill country leaves a wide field for research in ethology, zoology, botany, and geology; and as it is unlikely that any one, whose duties do not compel him to enter the country, will do so, except perhaps for a few weeks' sport, it would be well if those who have to enter could be induced to take note of, and report on the many points of interest that must necessarily fall under their notice.

(7.) The far greater number of the inhabitants, and all that live in fixed villages belong to the Kumbí, Warlí, or Rajpút castes, all those in one village generally belonging to the same caste. These villagers till the ground to a small extent, and for food supplement the small animals, which they shoot with

Inhabitants.

arrows, with fruit, coarse rice and náglí. Though their food is scanty, they drink very hard, the Parsees having a good trade in toddy and mahwa liquor. This latter tastes and smells somewhat like Kirsch-wasser, and the first batch of each brew is above proof, the second quality being about as strong as ½ gin and ½ water. Such is the liquor of which a man will consume large quantities in a day, with the thermometer rising above 100° in the shade. While the mahwa flowers are falling, the people distil for themselves, but have no idea of collecting a private store. The people wear very little clothing, except in the neighbourhood of the larger villages of the plain. Every man carries a small sickle shaped knife in the string of his *langoti*. Their huts have wattle walls of the tall boru grass stalks with a roof of the same covered with "pullies" of hay; the latter they seem invariably to place stalk ends down-wards, while the fan shaped part lies above; this arrangement looks as if it must hinder the rain from running off; indeed I do not think the people attempt to keep out the wet effectually. They are a miserable looking lot, ugly and weak, with stringy limbs and potbellies, that made my khalasies remark with contempt that all the men had "aurat ke pet" (thereby showing a profound ignorance of what often takes place in the ranks of luxury). Lung and chest complaints, and the skin diseases, due to poverty of blood and dirt, seem common among them. Fevers too are of course very prevalent. The statistics I have collected about the villages I visited seem to point out that the population is rapidly decreasing, the proportion of children to adults being as 34 is to 59. Indeed the small number of children met with is striking. In practice the people seem to be monogamous. They are very shy of strangers, occasionally flying as if panicstricken, but as a rule they soon come back, and are very civil and obliging. Their curiosity in some matters is as remarkable as their apathy in others. A crowd of men have frequently sat and gazed at me steadily, watching my every movement, but of that crowd several probably had never been 10 miles from their village, except in the direction of the nearest town. Sometimes however they will suddenly desert their villages and migrate after the manner of the Bhíls. The aboriginal Bhíls are now very few in number, and rarely met with except in the retinue of their chiefs, since if warned of the approach of a stranger they will desert their habitations at once, and if surprised in the woods will flee and hide almost before one is aware of their presence. They are slighter and smaller than the other races, and are chiefly noticeable for their extreme blackness, wild appearance, and scantiness of clothing. They live chiefly in bough huts, which may often be met with deserted. The Bhíls having strange superstitions, and at once migrating if they think their locality is unlucky or haunted. They will seldom remain a fortnight in one place. They feed on all sorts of vermin and garbage—many roots, and all fruits coming with them under the head of food. They are a dirty and most degraded race, having no notions of equity or honour. Their one happiness is to get drunk. At Pimprí I saw the Bhíl Rájá or naique of that Dáng. He is said to be the best of the lot, but even he is only sober in the early morning; he possesses an elephant, but the state he keeps up is very small. Besides the inhabitants proper there are parties of Hindoo and Mussulmán traders, called Banjárás, who are continually bringing in salt and taking out rice, náglí, and the like, carried in double bags by large droves of bullocks. The whole of a family marches together, and they encamp at night within walls built up with the bags. The women are very well dressed and have a sort of head dress peaked at the back over which the sárí passes. Also there are the people employed by the Forest Department. All the cartmen I met with were Musulmáns.

Language. (8.) The language spoken on the western edge of the hill country is Guzerathi, but soon changes to a corrupt Marathi which is very difficult to understand.

Animals. (9.) Any one who has plenty of spare time may amuse himself very well here. Tigers, panthers, bears, boars, bison, sámbar, bekre, and in the low ground hares are all to be met with if suitable arrangements be made.

Birds. (10.) The birds, are in large numbers, and of all sizes and colours from the large black and white eagles to the tiny humming birds. A very interesting collection might be made, and I regret that I am unable to give the names of the many varieties that I was able to notice. A list of the local birds would without doubt be of great value to the ornithologist.

Reptiles. (11.) I saw some very fine rock snakes, one couple about 9 feet long. Lizards, small and large, are in great variety.

Insects. (12.) Scorpions and centipedes are common, especially the latter, so that one has always to be on one's guard against them. The small black centipede seems to be the most common. Of *insects proper* the lepidoptera make a beautiful show. Often during the heat of the day pairs of gaudy butterflies have chased each other round and round my observatory tent on the hill top, and rested on the ropes within my reach. Beetles too of every colour and size, locusts, tree suckers (which drive their long probosces through the soft white bark of certain trees) and two or three sorts of mantis are very common. I saw some very fine spiders, notably one large variety of a light grey colour with handsome black markings on the body and along the thighs.

Botany.

(13.) The trees that strike the eye most are:—the tall Saouwar or Red Silk cotton tree, *Bombax Malabarica* (Hooker), with its magnificent show of crimson flowers, followed by seed pods containing the silk cotton; the Bhíls gather this when the pods are half ripe to make into tinder; it also makes good stuffing for pillows.

The Khandol *(Sterculia urens)* a bare white tree with gaunt leafless arms, looking ghostlike by moonlight; it has tufts of velvety, puce-coloured, star-shaped flowers; the soft white wood is used for making into platters, as it does not warp in drying.

The Sagwanor Teak tree *(Tectona grandis)*, with tall straight trunk.

There were few large trees in the parts I visited, the Pimprí valley having been cleared of them for building the Bombay navy. Towards the interior of the Dángs there are very fine trees.

The Sisoma or blackwood tree *(Dalbergia latifolia)* I found in large quantities in the neighbourhood of Ghusmáe Mátá, and to the northeast, growing to a thickness of 18 inches; for upholstery and cabinet work it is of course very valuable.

The Khair tree *(Acacia catechu)*, valuable owing to the terra japonica obtained by boiling the heartwood and unripe seeds. The heartwood is cut into chips by the men, and the boiling is superintended by the women; each woman has in front of her two rows of 6 pipkins each in which the chips are boiled; in the centre are two larger pots, into which the concentrated 'káth' from the smaller pots is collected; here it is allowed to thicken still more, and finally is extracted in portions as large as can be taken up in the fingers, and left to dry in the sun. There are several manufactories in the Dángs; the people who make the káth are of a low race, and filthily dirty; there is supposed to be some secret in the process. The terra japonica is used in betel chewing, and also exported for tanning purposes.

The Am *(Mangifera Indica)*, the Jungle Mango.

The Amli *(Tamarindus Indica)*, valuable for its fruit and giving good wood for building purposes.

The Panas, or Jack Tree *(Artocarpus Integrifolia)*, with its huge fruit with peculiar shagreen exterior.

The Bar *(Ficus Benghalensis)*, the well known banyan tree.

The Mahwa *(Bassia latifolia)*, from the flowers of which the 'daru' liquor is made.

The Dharí *(Grislea tomentosa ?)*, a low tree with thorny stem, and beautiful bunches of tubular scarlet flowers.

The Waras *(Heterophragma Roxburghii)*, a small tree with bunches of scalloped and crimped white flowers.

There were several kinds of trees from which, if wounded, red sap exudes, from which strange sight the idea of the enchanted wood of Tasso, and of other similar wonders probably sprang.

Geology.

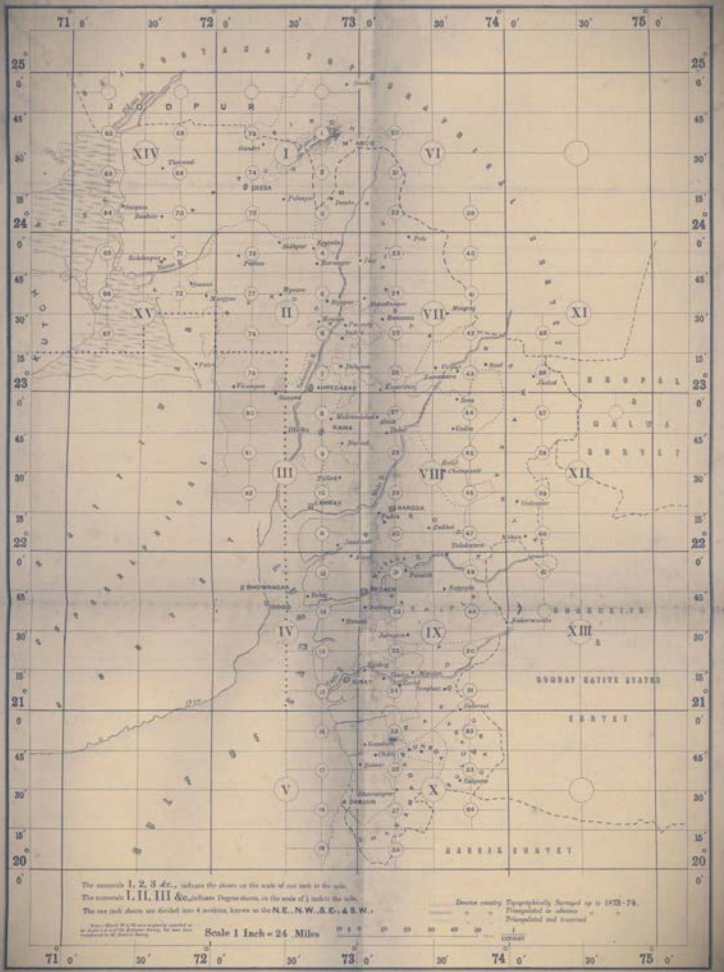
(14.) The whole of the hill country consists of 'Deccan' trap. The hills are all capped with thick strata of dark basalt, varying in texture but generally finely crystalline, and containing much iron. It is occasionally slightly columnar in structure. The sides of the hills below the precipitous capping are covered with debris of the rocks above; but where rock masses project from the loose stuff, they generally appear to be less compact than those above. As I have already mentioned, the spurs of the hills rise in the characteristic steps. In the beds of the rivers I generally noticed that the rock was considerably speckled with small felspar crystals, and also showed much hornblende when fractured. The boulders were of many different kinds, most of them close grained and crystalline; some however being very porphyritic, some full of the magnetic oxide of iron which rusts in the cracks into the peroxide, and some very full of slender prismatic crystals of what I believe to be natrolite. However I had not the means by me for determining the mineralogy, and I could not afford to carry about specimens with me.

Looking down from a high hill, it is at once evident that all the configuration of the ground is simply due to the erosion of water, but at the same time the stupendous result is almost bewildering; no other natural agent could have carved out the steep, deep, and narrow valleys through the horizontal strata; but the amount of power and time required for the process cannot be calculated. This does not of course refer to the strangely tilted peaks in the ghâts, above referred to, which show unmistakeable signs of the immediate proximity of volcanic force.

Having been warned previously to my entering the hill country that the water, even if boiled and filtered, would be unfit for drinking purposes, and that those who drink it would be sure to suffer from fevers and diarrhœa, I took with me a portable still, which with very little trouble supplied me and the Christians and Mahomedans of the party with water for drinking and cooking purposes. The Hindoos objected to using it, and it would have been of little good giving it to them, as on the march they drink from any pool near. I believe that it is principally owing to the use of the distilled water, that my servants and I were very free from sickness, while all the peons and khalasies had several attacks of fever and diarrhœa, although I made them take quinine almost every day. I therefore strongly recommend the use of a portable still in districts where the water is known to be bad.

GREAT TRIGONOMETRICAL SURVEY OF INDIA

INDEX CHART OF THE GUZERAT TOPOGRAPHICAL SURVEY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BROACH
SURAT
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GOGHA
DHOLKA
DHANDHUKA
GOGHO
BHOWNAGAR
DHOLA
JAFFRABAD
Jodhpur
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Pahlenpur
Deesa
Radhun
Sooigam
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Cambay
Nurwul
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Viramgam
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Jhalawar
Jhalawar
Kolhapoor
Kolhapoor
Kotda
Kotda
Gundul
Gundul
Jetpore
Jetpore

TABULAR STATEMENT OF WORK IN GUZRAT, DURING THE FIELD SEASON 1873-74.

Triangulation.

Observer's Names.	Instrument used.	Area triangulated sq. miles.	No. of Stations visited.	3 Angles observed.				2 Angles observed.				Remarks.
				Triangles.	Triangular error.	Error per mile.	No. of Heights.	Triangles.	Error per mile.	No. of Points.	No. of Heights.	
					"							*Approximate. [rays cut.
Lieut. J. E. Gibbs, ...	10" by Troughton & Simms	20*	24	23	17·1	Not computed	22	14	Not computed	7	...	Ray Trace Triangulation 45
Do. ...	Do. do.	490	11	16	2·8	1·1† inch	11	59	4·0‖ inch	32	32	Dangs △n† mean diff. of 8 common sides. ‖ Mean diff. of 20 common sides.
Mr. A. Christie, ...	6" by do.	600	79	125	19·7	9·1‡ „	58	333	5·1¶ ft.	200	...	Net-work △n over sheet 31—96 miles of ray cutting—22 rays. ‡ Mean diff. of 60 common sides. ¶ Mean diff. of 50 common sides.
„ E. J. Connor, ...	Do. do.	540*	120	171	12·7	5·7§ „	114	261	Not computed	130	...	One longl., and two meridl. series in sheet 78 and part of sheet 79. § Mean difference of 52 common sides.
	Total, ...	1650	234	335	...	...	205	667	...	369	32	210 stations have had their elements computed.

Plane Tabling 4 in. = 1 mile.

No.	Names.	Plane Tabling sq. miles.	Stations per sq. mile.	Remarks.
1	Mr. A. D'Souza* ...	44	9·5	*Also instructed Native Surveyors in the new method of surveying, and new men in the use of the plane table, and generally supervised and examined their whole work. The other assistants also examined some work.
2	„ C. H. McAFee, ...	33	13·4	
3	„ G. D. Casson, ...	51	5·7	
4	„ A. H. Bryson, ...	78	12·9	
5	„ G. Hall, ...	112	16·4	
	Native Surveyors.			
1	Raoji Narayen, ...	111	13·1	† Joined Head Quarters for office work on 3rd of January and returned to plane tabling on the 13th of February. ‡Resigned on the 10th of February, re-engaged 11th May. §Joined Head Quarters for office work on 7th of February being too ill for work in the field and returned to plane tabling on the 21st March. ‖See also Traversing.
2	Bhou Govind, ...	100	16·6	
3	Balwant Govind,† ...	61	14·5	
4	Luxomon Ghorpuray,‡ ...	34	9·9	
5	Mokand Dinkar,§ ...	44	9·2	
6	Ganesh Narayen, ...	58	18·8	
7	Ganesh Bapuji 1st,‖ ...	21	21·6	
	Total, ...	746¶	average 13·5	¶Including overlap.

Traversing.

No.	Names.	Linear miles of Traverse.	Hypothenusal error per 1000 links.	Remarks.
	Native Surveyors.			
1	Gopal Vishnu, ...	215·933	0·9 links	In all 1268 Traverse Stations have had their elements computed.
2	Ganesh Bapuji 1st, ...	74·179	1·2 „	
3	Ganesh Bapuji 2nd, ...	236·547	2·4 „	
	*Revenue Surveyors.**			* Not including Ganesh Bapuji 1st whose days employed &c. are under 'Plane Tabling.'
1	Kubar Parbhu Dass, ...	107·037	1·5 „	
2	Parbhu Kisor, ...	89·890	1·0 „	
3	Jugal Mansukaram, ...	106·533	0·7 „	
4	Gopall Ganesh, ...	71·058	0·7 „	
5	Lalu Ambaram, ...	92·997	1·4 „	
	Total, ...	981·645	average 1·2 links	

Extract from the Narrative Report—dated 20th November 1874—of Captain H. R. THUILLIER, R.E., Officiating Deputy Superintendent 1st Grade, in charge of the Kumaun and Garhwal and the Dehra Dun Survey Parties.

(1.) During the recess of 1873, while Lieutenant J. Hill, R.E. was in charge, the party was employed on computations and in preparing the fair maps of Kumaun, surveyed during the previous field season. Four shaded and two skeleton sheets were completed and sent for publication before the party took the field.

Recess of 1873.

(2.) On the 1st October 1873, I received charge of the Kumaun and Garhwál Party from Lieutenant Hill, R.E.

(3.) The only portions of Kumaun and Garhwál which then remained to be surveyed, embraced some of the highest ground in the great Himalayan range. To attempt surveying such elevated regions during the winter months, would in all probability end in failure. Such ground can only be attempted with a fair prospect of success during the autumn and spring months. I was therefore instructed to postpone the prosecution of the Kumaun and Garhwál Survey until the spring of 1874, and in the interim to employ the party in making a survey, on the scale of 4 inches to a mile, of such portions of the district of Dehra Dún, as are not included in the Government Forest lands which were being surveyed independently by Captain F. Bailey, R.E. of the Forest Department.

Portions of Kumaun and Garhwál remaining to be surveyed.

Dehra Dún Survey.

(4.) As there was no separate demarcation establishment to precede the Survey, the Superintendent of the Dún was referred to for assistance regarding the demarcation of the village and other boundaries, as soon as the Survey was determined on. The last settlement of the district was completed in the year 1864, and though the boundaries are tolerably well demarcated with permanent pillars, they are not sufficiently numerous to define the boundaries for the purposes of a Survey. The Superintendent promised cordial support and assistance, and orders were promptly issued to Zamíndárs and Grant holders to define their boundaries by temporary marks at bends and turns, where not otherwise defined by natural features, and to have the lines cleared between them ready for the Survey.

(5.) On assuming charge of the Kumaun and Garhwál Party, the organization consisted entirely of European Surveyors. For the large scale Survey of the Dún, the system of plane-table surveying which had been the only method made use of for the small scale Surveys on which this party had hitherto been employed, required modification. For the flat ground, of which there is a considerable amount in the Dún, in which boundaries are the chief object, the ordinary method of chain surveying had to be resorted to. For this process it was necessary to employ native agency, otherwise the cost of such operations, which involve considerable additional labour, would be materially enhanced.

Organization of the Party.

(6.) One of my first duties therefore was to change the organization by having a proper proportion of Native Surveyors to the Europeans. I found however it was impossible to obtain trained men, and I was therefore forced to entertain men who were entirely ignorant of surveying and to have them instructed in the special work which we required. The labours and difficulties attendant in training a large number of men need not be expatiated on; it is sufficient to say that without an exception all the men were perfectly ignorant of the rudiments of surveying, and were generally unacquainted with English, which increased the difficulties of instruction. To teach such men the use of delicate instruments would have been a labour involving considerable delay and in many cases perhaps failure; and as the working season was passing on, it was an object of importance to utilize as far as possible the services of these men while the field season lasted.

Reorganization.

(7.) I decided therefore to have them taught the use of the simplest instrument for traversing, *viz.*, a circular protractor (ordnance pattern) mounted on a plane-table. This method of traversing had been introduced by Lieutenant Hill with success in the Bhábar and Tarái tracts of Kumaun. A circular cardboard protractor, graduated to quarters of a degree from left to right, commencing from the south, is mounted on an ordinary plane-table, and the magnetic meridian line, found in the usual way at a trigonometrical station, is marked on it. For traversing, the plane-table is set up by the long magnetic needle, the azimuths of back and forward stations are taken by placing the edge of the sight rule over the centre of the circle, intersecting the objects, and then reading the bearings off the graduated circumference. The azimuths having been read off a circle of large diameter, are susceptible of considerable accuracy, and being referrible to the true meri-

Method of Surveying.

dian are all the more quickly plotted on an ordinary graticule, than magnetic bearings, and require no correction if it is necessary to compute the traverse. The observations also can be taken more quickly than with the prismatic compass, as it is not necessary to wait between them for the needle to come to rest.

(8.) The field operations commenced early in November and the members as per margin were employed for various periods during the season in the Dún work. Lieutenant Gore R.E. was deputed on special work to fix trigonometrically two stations at Roorkee, selected by Colonel Tennant, R.E., for the observations of the Transit of Venus. Mr. Ryall was entrusted with the duty of training the Native Surveyors and superintending the boundary surveys; Messrs. L. Pocock and Kinney with triangulation, and to Messrs. Litchfield, Wrixon and I. Pocock were consigned the main circuit traverses.

E. C. Ryall Esq.
Lieut. St. G. Gore, R.E.
Mr. J. Low.
" L. Pocock.
" J. Macdougall.
" H. Todd.
" T. Kinney.
" E. Wrixon.
" E. Litchfield.
" I. Pocock.
16 Native Surveyors.

Out-turn of work.

(9.) Owing to our taking the field late, the new nature of our work and the difficulties and delay in training the whole of the Native Surveyors, the out-turn of work has been small, but I trust will be considered satisfactory, considering that we had to initiate a new system and teach all the Native Surveyors in a body. The area topographically surveyed on the scale of 4 inches to a mile was 40,051 acres, or about 63 square miles; the triangulation has covered an area of 529 square miles: 271 linear miles of main theodolite traverses and 577 miles of boundary traverses have been run.

Origin of Survey.

(10.) The East End Dehra Dún Base-Line Station was adopted for the initial or starting point of the Survey, and being well and centrically placed will be maintained as the origin for the whole of the Dún Survey.

Theodolite traverses and their errors.

(11.) The traverses, including those of the boundaries, were all reduced in the field and found to stand the usual tests in a satisfactory manner. Every precaution was taken to insure accuracy of results. The lines were in all cases traversed with two chains of a different unit, whose lengths were from time to time tested with the standard, and corrected accordingly. The directions of the main traverse lines were laid out with the object of connecting boundary pillars at sufficiently close intervals so as to form proper checks on the village boundary traverses. It was found that this could be done in most cases by running them along the main roads, streams, &c. so that in addition to establishing check points for the minor traverses, they include a large amount of topographical detail which was plotted on the plane-tables before they were sent out to the Plane-Tablers. In addition to these checks, 51 boundary pillars were fixed trigonometrically, so that the boundary traverses are in all cases well tied in. The main theodolite traverses were in all cases run between trigonometrical stations. On reference to the tabular statement at page 41—a it will be seen that in 55 traverses, the united lengths of which amount to 271 miles, the average difference from the corresponding trigonometrical values is 0·74 per 1000, and the average closing angular error 21″ per station.

Boundary traverses and their errors.

(12.) The boundary traverses comprise 184 villages and estates. These were done entirely by the Native Surveyors, whom we had trained at the commencement of the field season, and considering their inexperience, and the delays met with in prosecuting their work owing to the want of demarcation of the boundaries, the result I think is as much in quantity as could be expected, and in quality very creditable, considering the rough ground which a large portion of the Dún consists of. I have classified these traverses under two heads according to the nature of the ground traversed. It will be seen from the tabulated statement that in fair level ground in 124 traverses, the united lengths of which amount to 403 miles, the average closing error is 1·97 per 1000. In the rough and hilly ground, in 58 traverses with a united length of 174 miles, the average closing error is 4·71 per 1000. This error, though apparently large, is wonderfully good for the nature of the ground traversed over. As the Dún chiefly consists of broad plateaus intersected by deep ravines, it is a natural arrangement that the boundaries of villages &c. should be defined by such natural features. This is the case in the majority of boundaries, and in the northern portion of the valley at the foot of the Himalayas, the ground is very hilly, rugged and broken. Chain measurements in such ground, unless reduced to the horizontal level, would be quite untrustworthy. I therefore provided the Surveyors with rough wooden clinometers, graduated to degrees, by which they observed and registered the angles of inclination. In many cases inclines of from 20° to 50° have been chained over; adding to this the roughness of the ground, especially in the ravines where large boulders are met with in great abundance, the error of the work in land of this character will not be wondered at. To show the intricacies of the boundaries, I have appended a column in the detail of work, giving the number of traverse stations, as they increase the labour of the work and add to the probabilities of error. This gives the average distance between each station to be only 6¼ chains.

Obstructions and delays.

(13.) The boundary work, owing to the delay in training the Native Surveyors, cannot be said to have been fairly started till the end of December, and as these preliminary traverses were required to be surveyed,

reduced and plotted before the topography could be taken up, the plane-tabling was not commenced till the beginning of March, and the out-turn of topography therefore has been necessarily very small. The progress of the boundary traverses also was considerably retarded from causes beyond our control; the chief cause of delay being due to inefficient demarcation. Although orders were issued on the subject by the Superintendent of the Dún in October, it was found that they had not been carried out and consequently the non-attendance of the Zamíndárs or properly qualified men to point out the boundaries was a source of much trouble; complaints were constant and progress slow. The Surveyors in many cases found that no steps whatever had been taken for preparing the boundaries for the survey, and in order to prevent further delay, often had to clear their own lines. They were generally entirely dependent on the attendance of the Patwáries for marking the boundaries at the actual time of survey, a system which naturally would cause delay under the most advantageous circumstances, but when combined with the ignorance and indolence which most of the Patwáries of the Dún evinced, proved fatal to the rapid progress of the work, and much valuable time was thereby lost. Boundary disputes, which were numerous, tended to cause further delay. Some of these were however amicably settled at the time of the survey through the aid of the Peshkár or Cánúngo, whose services had been kindly placed at my disposal by the Superintendent of the Dún; others however were beyond his powers, and as there was no settlement officer at hand to adjudicate and adjust them, they had to be abandoned. Such disputed portions I, at one time, had surveyed as claimed by each owner, but this I found was waste of time, as generally neither of the claimants were right.

Triangulation and traversing in advance of the detail Survey.

(14.) The amount of triangulation and traversing completed in advance of the portion topographically surveyed, covers an area of 198 square miles. This embraces 18 plane-table sections which are therefore quite ready to be topographically filled in, and will be taken in hand at the commencement of the field season.

(15.) I now proceed to report separately on each Officer's work, the details of which are tabulated on page 41—a

E. C. Ryall Esq.

(16.) Mr. Ryall was entrusted with the duty of training the Native Surveyors for the boundary traverses, and took the field on the 10th November. Messrs. Litchfield, Wrixon and I. Pocock were also attached to him temporarily for the purpose of being employed in main circuit traverses. As previously stated, the natives were thoroughly ignorant of any kind of work connected with surveying; the assistants also were inexperienced both in this method of field work and in the reductions, and the task of instructing some of them and the whole of the Native Surveyors devolved on Mr. Ryall, who was consequently not able to take any very active share in the actual survey operations. Early in December, five of the Native Surveyors who had been trained, were transferred to Lieutenant Gore, R.E., for employment under him. With the remaining men, Mr. Ryall was instructed to take up the village boundaries in the Western Dún, north of the main road running from Dehra to Ambári.

(17.) He reports that no actual boundary work was commenced till the first week in December, and that owing to the inexperience of the Native Surveyors, much that was done during that month had to be revised, so that the out-turn of work in December was very small, only three or four villages being successfully surveyed. The work done by the Native Surveyors in January, though still unsatisfactory, was found to be an improvement on their former attempt. On 14th February, Mr. Ryall transferred seven of the Native Surveyors to Messrs. Kinney and Litchfield to assist them in filling in the interior details, and proceeded further west carrying on the boundary traverses. At the end of March, Mr. Ryall was relieved from his duties connected with the Dún Survey, in order to carry on the Kumaun and Garhwál Survey which had been suspended during the winter. I am much indebted to Mr. Ryall for his exertions in training a large number of men and rendering them practically useful in a few months in a difficult country.

Lieutenant St. G. C. Gore, R.E.

(18.) Lieutenant Gore, R.E. was posted to the party on 1st August 1873, and was sent at the commencement of the field season on some triangulation to fix points at Roorkee, in anticipation of the observations of the Transit of Venus. Lieutenant Gore started on this duty on 6th November. Two stations selected by Colonel Tennant, R.E. were fixed by observations to and from the principal stations of Chándípahár and Doíwála, which are situated in the Siwálik Hills; other permanent objects *viz.* the Dome of the College, Foundry Chimney, &c. were also fixed.

(19.) On the completion of this undertaking, early in December, I sent Lieutenant Gore with a party of five Native Surveyors who had been trained by Mr. Ryall, to take up the survey of the village boundaries, commencing from the Dehra and Shorepur road and working westwards. Lieutenant Gore continued on this duty during the remainder of the field season, and by his energetic and systematic arrangements produced a large amount of boundary work out of his natives. In addition to this he made a large scale survey of the Harbanswála and Arcadia Tea plantations, on the scale of 20 inches = 1 mile, comprising an area of about 640 acres. He closed work on 27th May. Lieutenant Gore has become thoroughly acquainted

with the practical operations of the Survey and has rendered me much valuable assistance.

Mr. J. Peyton.

(20.) Mr. Peyton was not employed in the field, his services being required in the drawing branch of the Head Quarters' Office where he also superviséd the Native Draftsmen belonging to this party, who remained in Quarters preparing the skeleton sheets of Kumaun and Garhwál. Mr. Peyton was transferred to the Guzerat Party from the 1st May.

Mr. C. J. Neuville.

(21.) Mr. Neuville was appointed to this party on 1st November, but owing to the state of his health which the Civil Surgeon of Dehra certified was quite unequal to out-door work of any nature, and that any exposure would be attended with considerable risk, his services were utilized in the head camp in carrying on the current Office work and in the computations of the triangulation and traverses which involved a considerable amount of labour.

Mr. J. Low.

(22.) At the end of the field season of 1872-73, Mr. Low had received orders from Lieutenant Hill, who was then in charge of the party, to continue his field operations in Kumaun throughout the summer and autumn months. This portion of his work will be reported on under head of the Kumaun and Garhwál Survey. He returned to Dehra about 20th December, and after a few days' rest commenced operations in the Dún. Up to the middle of February he was employed in traversing and though his progress was not rapid at first, owing to want of experience in work of this nature, the results were good. He was afterwards employed on triangulation in the Siwálik Hills, east of the Mohan Pass. This undertaking was taken up chiefly for the purpose of furnishing points for Captain Bailey's Survey of the Siwáliks. Mr. Low commenced observations on the 7th March and closed work on 27th May, completing an area of 83 square miles. The details of his work will be found in the tabulated return at page 41—a. His observations were much hindered by the hazy weather which invariably prevails during April and May, and his progress was further retarded by the physical difficulties of the Siwálik Hills, the precipitous nature of which caused much delay in moving from point to point. Mr. Low had thus been for 18 consecutive months on field duty and has worked hard and well.

Mr. L. Pocock.

(23.) Mr. L. Pocock took the field on 8th November and was employed throughout the season in triangulating. He executed a net-work triangulation covering 267 square miles, consisting of 104 points visited and 451 fixed by intersection, the heights of 103 of which were determined by vertical observations. Mr. Pocock is a rapid and excellent observer and has throughout given me every satisfaction. Unfortunately his health is far from good and he cannot stand much exposure. His progress was somewhat retarded on this account, but he worked hard till the beginning of May when his health broke down, and on submitting a medical certificate, he was permitted to proceed to recess quarters where he was employed in bringing up the computations of his work.

Mr. J. W. Macdougall.

(24.) Mr. Macdougall was transferred to this party on 1st January, but as his services were required in the Computing Office, he did not join till the end of that month. He was employed till the end of April in the office in computations. I was much pleased with his steady application and industry. He is very energetic and hardworking, but his want of accuracy is a great drawback to his usefulness as a computer. During May he was employed in traversing in and about the station of Dehra. The results of his work were very satisfactory and will be found detailed in the tabular statement.

Mr. H. Todd.

(25.) Mr. Todd was employed in quarters till 23rd February in preparing one of the degree sheets of Kumaun and Garhwál, and in the current work connected with the publication of the one inch sheets. He joined my camp at the end of February, when I instructed him to take up the topography of section 17 and the western half of section 28. He commenced plane-tabling on the 12th March and completed the above sections single handed, there being no Native Surveyors available at that time to assist him. On 4th May he took up the topography of section 16 with two Native Surveyors, each with a plane-table, one of whom however had received no instruction in plane-tabling. Mr. Todd had therefore to train him *ab initio*. With the exception of a small portion in the S. W. corner, this section was also completed. The portion of country in which Mr. Todd worked is a level plain, partly cultivated and partly waste and forest land, with a fair amount of detail which had to be delineated principally by the laborious process of chaining. At the end of March, I inspected Mr. Todd's work and found it very carefully done. His total area comprises 22,507 acres, which was executed at the rate of 16 square miles per mensem. Mr. Todd is a very careful and accurate Surveyor and though his health was not good towards the end of the season, he continued assiduously at his work till 23rd May and has proved himself to be a valuable assistant both in the field and in office.

Mr. T. Kinney.

(26.) Mr. Kinney took the field on 25th November and was first employed in triangulating in the neighbourhood of Dehra. On the 15th December, on the completion of this piece of work, I attached him to Mr. Ryall to assist him in the training of the Native Surveyors and in the reduction of the boundary traverses. On 16th January, he was deputed to connect certain boundary pillars with trigono-

metrical stations so as to furnish checks for the village traverses. He was employed in this way with Mr. Ryall till the middle of February, by which time the preliminary work was sufficiently advanced for the topography to be taken up. To Mr. Kinney was allotted the western half of section 38 and the eastern half of section 28; he was provided with three Native Surveyors, all of whom however he had to train in plane-tabling, their previous work having been confined to boundary traverses. He commenced the topography on 10th March and on closing work for the season on 27th May, had completed an area of 13,530 acres which was at the rate of 14½ square miles per mensem. The greater portion of this piece of country is very highly cultivated and with a large amount of detail, and considering that a great portion of his time was taken up in training three Sub-Surveyors, his out-turn may I think be considered very creditable.

Mr. E. P. Wrixon.

(27.) Mr. Wrixon was transferred to this party from 1st October and was employed throughout the greater part of the field season in carrying main traverses for fixing trijunction pillars, so as to form proper checks on the boundary traverses. He subsequently, for the same object, executed some minor triangulation near the foot of the hills where the ground would not admit of traverse lines being run between trigonometrical stations. His work will be found detailed in the tabular statement and stood the usual test very satisfactorily. I am glad to be able to report favorably of Mr. Wrixon's exertions. He still requires a good deal of supervision, but his system of working has considerably improved since he has been attached to this party.

Mr. E. Litchfield.

(28.) Mr. Litchfield took the field on 24th November and after a few days' instruction in traversing, he was sent to carry on main circuit traverses over ground to the N. W. of Dehra. These circuits embraced comparatively very rough ground, the traverse lines running into and over numerous deep ravines. Under the circumstances, the results of his labour which will be found in the tabulated return, are very creditable. On the completion of this piece of work, he was employed for a month and a half in assisting Mr. Ryall in the reduction of traverses, and subsequently in the beginning of March, took up the topography of section 37 which he was employed on till the 4th April, when, on account of his services being required for the Kumaun and Garhwál Survey, he closed work in the Dún. He completed an area of 4,014 acres at the rate of about 11 square miles per mensem. His ground was much more intricate than the portions surveyed by Messrs. Todd and Kinney, hence the slower rate of progress.

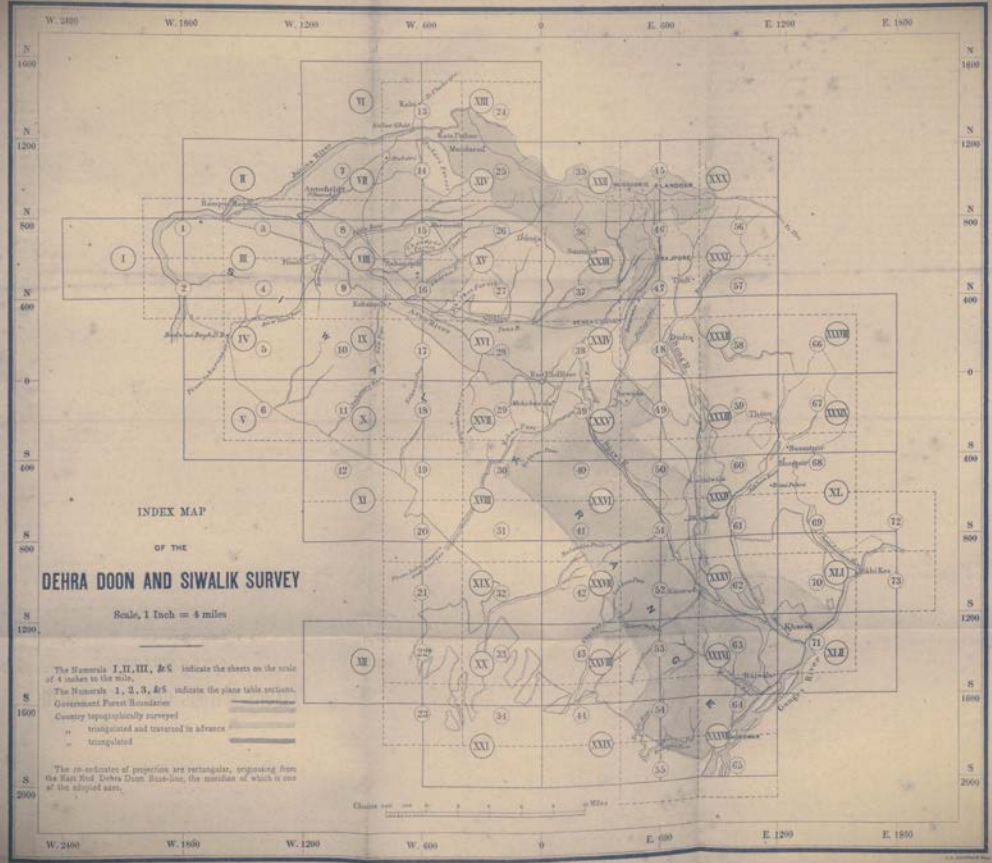
Mr. I. Pocock.

(29.) Mr. Pocock had hitherto done no independent field work, having been employed in the Office during the previous (his first) field season; he had therefore to be instructed in the method of traversing and connecting traverses together. In the beginning of December, he was deputed to carry a series of traverses from the E. End Base-Line through the valleys of the Asan and Jumna. His progress, owing to his inexperience, was at first slow and was further much retarded by the bhábar grass and khyr jungle through which his lines had to be cleared. Mr. Pocock applied himself very diligently to his work and promises to become a useful member of the Survey. Having been told off to accompany the party proceeding into Kumaun for the continuation of the survey there, he closed work in the Dún on 4th April. The detail of his work will be found in the tabulated return.

Native Surveyors.

(30.) The Native Surveyors have as a body done well and worked diligently, and considering they were all new hands, have done as much as could be expected of them. In flat even ground some of them have already done independent work in putting in the features, and with more practice, I have no doubt will improve and turn out good work. A few of the more intelligent men, I am in hopes, may be utilized in surveying the more rugged and hilly ground near the foot of the hills, but I fear it will take sometime to train them for work of this nature, which cannot be vested by the system of *partál* lines.

(31.) As the topography had to be taken in hand during the season, and check points furnished for the village boundary traverses, a very large amount of calculation had to be done in the field. I at first thought that the system of plotting the boundary traverses by protraction would have answered every purpose, but as the Native Surveyors were all unpractised hands and not good at the work, and the boundaries as a rule were very intricate, it was found that time would be saved by reducing all these traverses in the first instance. This laborious duty devolved chiefly on the Head Office and occupied a very considerable portion of my time. I have now however four natives thoroughly trained in these computations, which will relieve the European assistants of this irksome task.


W. 2400
W. 1800
W. 1200
W. 600
0
E. 600
E. 1200
E. 1800
INDEX MAP
OF THE
DEHRA DOON AND SIWALIK SURVEY
Scale, 1 Inch = 4 miles
The Numerals I, II, III, &c. indicate the sheets on the scale of 4 inches to the mile.
The Numerals 1, 2, 3, &c. indicate the plane table sections.
Government Forest Boundaries
Country topographically surveyed
" triangulated and traversed in advance
" triangulated
The co-ordinates of projection are rectangular, originating from the East End Dehra Dunn Base-line, the meridian of which is one of the adopted axes.
Chains
Miles

DEHRA DUN SURVEY.

Tabular statement of out-turn of work. Season 1873-74.

Details of Triangulation.

OBSERVER'S NAMES.	Instrument used.	Area triangulated in square miles.	No. of stations visited.	No. of points fixed by intersection but not visited.	No. of stations whose positions and heights have been fixed.	No. of stations whose positions only have been fixed.	No. of hill tops cleared of forest.	Average number of trigonometrical points per square mile.	Average area in square miles to each trigonometrical height.	No. of triangles of which all three angles have been observed.	Mean triangular error.	No. of triangles of which only two angles have been observed.	No. of trijunction boundary pillars fixed.
	Inch.										"		
Lieut. St. G. C. Gore,...	14	158	4	4	0	8	0	0·05	...	4	1·5	4	
Mr. J. Low, ...	8	83	44	106	53	92	37	1·75	1·6	68	8·9	221	
„ L. J. Pocock, ...	12	267	104	451	103	452	0	2·08	3·0	69	15·5	782	15
„ T. Kinney, ...	7	11	13	36	0	47	0	4·27	...	16	50·4	60	7
„ E. P. Wrixon, ...	7	10	22	0	0	20	0	2·00	...	17	24·3	15	29
Totals, ...	...	529	187	597	156	619	37	...	...	174	...	1082	51

Details of topography. Scale 4 *inches* = 1 *mile.*

NAMES.	Area in acres.	No. of Plane Table Stations.	No. of acres per Plane Table Station.	Out-turn of work in acres per diem.
Mr. H. Todd, ...	22,507	2,447	9·2	331
„ T. Kinney, ...	13,530	1,220	11·1	301
„ E. F. Litchfield, ...	4,014	622	6·5	223
Totals, ...	40,051	4,289	8·9	...

Details of traversing.

THEODOLITE TRAVERSES.

NAMES.	Linear miles of traverse.	No. of stations.	Average error per 1,000 links.	Average angular error per station.
			'	"
Mr. J. Low, ...	18	84	0·63	16
„ J. Macdougall, ...	26	87	0·78	16
„ E. P. Wrixon, ...	129	292	0·60	28
„ E. F. Litchfield, ...	11	70	0·89	11
„ I. S. Pocock, ...	87	149	0·81	34
Totals, ...	271	682	Mean 0·74	Mean 21

PLANE TABLE AND PROTRACTOR TRAVERSES.

	Nature of ground.	Linear miles of traverse.	No. of stations.	Average error per 1,000 links.
Native Surveyors	Fair, ...	403	4,404	1·97
	Rough and hilly, ...	174	2,666	4·71
	Totals, ...	577	7,070	

KUMAUN AND GARHWAL SURVEY.

(32.) The extent of country which remained to be surveyed in Kumaun and Garhwál was estimated at about 3,600 square miles and consists of ground of very great altitude, physically the most trying and formidable to Surveyors. A considerable portion of this tract about the high ranges, probably one half, may be said to be simply impracticable and can really be only reconnoitred. It was arranged that this unsurveyed portion should be placed under the charge of Mr. E. C. Ryall, who by his long and varied experiences in mountain surveying was specially fitted for such an arduous undertaking.

Arrangements for the continuation of the Survey.

(33.) The period during the year in which actual field operations can be carried on in such high altitudes being very short, it was arranged that the party should recess close to the scene of its operations, in order to avail itself of as much of the clear and mild weather as possible. The probable working period was estimated at 45 days before the rains and about the same number afterwards, though this of course depends a great deal upon the nature of the season. Almora being the nearest station to their operations, was selected for recess quarters.

Limited period of field operations.

(34.) The members as per margin were told off for the operations in Kumaun and Garhwál, Mr. McA'Fee having been transferred to this party from the Guzerat Survey in April and Mr. McCarthy from the Head Quarters' Office in February. The party assembled in Dehra early in April and after making their necessary arrangements for the campaign, started for Almora on 12th April.

E. C. Ryall Esq.
Mr. McA'Fee.
" Litchfield.
" I. Pocock.
" McCarthy.

(35.) At the close of the field season of 1873-74, Mr. Low was directed by Lieutenant Hill, R.E. who was then in charge of the party, on the completion of his topographical work, to carry a minor series of triangles from the base Húm H.S. to Punya H.S. up the valley of the Gorí to the Passes above Milam. Mr. Low however owing to unavoidable delays, as stated in Lieutenant Hill's narrative report for last year, did not finish his plane-tabling work till the end of June. It was not till the beginning of July therefore that he could commence his observations, which proved to be too late; for owing to clouds and bad weather Mr. Low after remaining one month at his first station Húm H.S. did not succeed in getting half a day's work. The state of his health then compelled him to apply for a month's privilege leave to proceed to Naini Tal for medical treatment. He recommenced his observations at his first station on 27th September, and from that time till 1st December he was steadily engaged in pushing on the triangulation. During this time he visited 24 stations ranging in height from 4,000 to 13,800 feet above sea level. The season was a particularly severe one, the first heavy fall of snow taking place so early as the 10th October. The establishment all suffered more or less in consequence, and six of the natives were severely frost bitten, one of whom I regret to say, lost all the toes of one foot; the other men recovered. Mr. Low had severe weather to contend with and his work involved a good deal of exposure. Although his area embraced a portion that had been previously triangulated, he fixed a number of additional points which rendered matters more easy for the plane-tablers.

Mr. J. Low.

(36.) Mr. Ryall has submitted the following report of the operations under his charge up to the time of returning to recess quarters at Almora in July.

Out-turn of work.

"My camp left Dehra on 12th April reaching Káládúngi on 26th and Almora on 2nd of May where I was detained till the 7th. In the meantime I was pushing on with the computations, while the Assistants under me were going on with the projection of their boards. At Bagesar, two marches out of Almora, I thought it advisable to split up my camp into two and march to our ground in separate detachments by different routes. By the time I got to the ground I had finished all the computation of the triangulation required for our work. When marching from Naini Tal to our ground the party suffered somewhat from the great heat in the valleys.

"Of the four Assistants, *viz.*, Messrs. McA'Fee, Litchfield, I. Pocock and McCarthy, none, with the exception of Mr. Litchfield, had had any training in hill sketching; it devolved on me therefore to train these three. In this duty Mr. Litchfield helped me greatly by taking Mr. I. Pocock in hand. I deputed Mr. McA'Fee to finish up about 14 square miles of P.T. section No. 57 and Mr. Pocock about 28 square miles of the same section lying to the north-east. After these portions were completed, Mr. McA'Fee was directed to take up P.T. section No. 63 and the western parts of section No. 62. I anticipated that the trigonometrical points lying to the west of these sections would not perhaps be sufficient to extend the sketching in them much to the eastward. I provided Mr. McA'Fee therefore with a 7-inch theodolite to enable him to lay down some additional points should he deem it necessary to do so and could find the time to extend the triangulation in that direction. Mr. Pocock, I arranged, should assist Mr. Litchfield by taking up the eastern parts of P.T. sections Nos. 56, 48 and 40. To

Mr. McCarthy I allotted the sketching of the Rálam valley, being a part of P.T. section No. 55.

"Having made the above dispositions, I proceeded to extend the triangulation taken in hand by Mr. Low last year. At first sight the conducting of a series of triangles into the Milam valley appears impracticable, but a few days' reconnoitring convinced me that it was feasible. I lost no time therefore in extending it. I found however that I could make no progress till 8 days after on account of unseasonable weather.

"The incessant rains that besieged the whole of Kumaun from 30th May up to 13th July with the exception of one day the 19th June, was an unusual circumstance and tended greatly to retard the progress of the work. After the 12th June however the weather, without apparently abating in the daily amount of rainfall, became so far favorable as to give to the Surveyors employed in sketching a few hours of the early morning. It became apparent therefore to all of us that encamping on the heights was necessary to enable one to take advantage of the few clear hours during the earlier parts of the day.

"I pressed on with my triangulation up to the Uttar Dhurra Pass. I found it impossible to observe at some of my stations and deferred visiting them to a future and more favorable time. The ascent to some of these stations is very steep the entire way; in others it is gradual for about half the distance only and none of these peaks I was informed had so much as 6 square feet of flattish ground for encamping on. It was clear that to visit these places it would be necessary to go up in one day, finish the observations and return again the same day. This the weather would not admit of my doing, for it generally takes me about 4 hours climbing to accomplish 6,000 feet, beginning at an altitude of 10,000 feet above sea level. It is not an easy matter to climb up precipitous ascents of rock, ice and snow in the day time and doing so at night is simply out of the question.

"The extent of triangulation finished by me covers an area of 460 square miles comprising 14 stations visited, of an average height of 15,500 feet above sea level. I closed work on 2nd July and got out of the Milam valley on the 7th when I was joined by Messrs. Pocock and McCarthy. I arrived at Almora on 14th July.

"Mr. McA'Fee began work on 24th May and having finished up the portion of P. T. section No. 57 allotted to him, proceeded with the sketching of P. T. section No. 63. Up to the 11th June Mr. McA'Fee was only able to accomplish in all 31 square miles of sketching, the weather being too unfavorable to do more. He unfortunately fell ill on that day and halted on his ground for 9 days with the hope of recovering, but as no improvement took place in the state of his health, he marched to Almora for medical advice. Mr. McA'Fee showed throughout great willingness and but for his falling ill, I have no doubt, he would have brought in a large quantity of work. The average height at which he worked, is about 8,500 feet and the highest point visited by him is 11,300 feet.

"Mr. Litchfield after training Mr. I. Pocock commenced work on his own ground on 26th May and notwithstanding the badness of the weather, pushed on with his sketching in a very creditable manner and completed 238 square miles of topography. The highest points visited by Mr. Litchfield are about 17,000 feet and the average height at which he worked is about 12,500 feet. Mr. Litchfield closed work on the 30th June and marched back to Almora where he arrived on 9th July.

"Mr. I. Pocock commenced his work on the 15th May under the supervision and training of Mr. Litchfield. In 6 or 7 days Mr. Pocock was sufficiently advanced to get on with his work independently. Considering all things and the badness of the weather Mr. Pocock made very fair progress completing the sketching of 149 square miles. The highest point visited by Mr. Pocock is about 16,000 feet above sea level, and the average height at which he worked is about 10,000 feet. Mr. Pocock closed work on 5th July and joined my camp on its way back to Almora on the 7th.

"Mr. J. McCarthy after being duly trained by me, commenced his work on 27th May. At first Mr. McCarthy got somewhat confused on account of the intricate disposition of the snowy peaks about him. I had an opportunity on the 12th June of meeting him and putting him all right. Mr. McCarthy did very well, turning out an area of 128 square miles. He worked at an average height of 15,000 feet above sea level, the highest point visited by him being about 18,000 feet. Mr. McCarthy closed work on 5th July and joined my camp on the 6th idem.

"It now remains for me to deal with such points in connection with the work as appear to me not to be irrelevant in a report of this kind. It is a generally received opinion among those who have not had experience of the hardships of moving about in mountains of considerable altitude that the undertaking is somewhat akin to a pleasure trip; that so far as regards health it is the finest thing; that the sight of glorious mountain scenery, the hard walks, the bracing air, &c., are changes that promote in every way the physique of those who go through those "pleasures." Having had a good deal of experience among mountains, I will give a rough sketch of what I think about the realities of mountain travelling in very high altitudes.

"The traveller who goes only to gratify his taste for sport and the traveller who goes with the double object of seeing strange places and enjoying mountain scenery, have easy times of it compared to what the Surveyor has to undergo. The Surveyor goes under an obligation and is

naturally anxious about his work. He has to visit places and climb mountains that an ordinary traveller never attempts. The former has to pass most of his nights on high ridges; the highest point that the latter ever visits is a Pass, and to that he has invariably a fair road and seldom passes a night at what one would call a very great elevation. Survey officers while working at very great elevations are much exposed to the distressing influences of rarified air and a cold temperature, which I cannot help thinking must be injurious to the constitution. To the hardships that they are exposed might be added the risks they constantly incur when journeying from mountain top to mountain top, for they very rarely have the luxury of using foot-paths. The work of carrying loads therefore becomes singularly harassing to the inhabitants who are summoned to act as coolies; and at elevation averaging over 12,000 ft. it becomes impossible for them to carry the standard weight of 20 seers per cooly. Guides of the district of Bhot in Kumaun and Garhwál are only acquainted with such localities as shooting and grazing grounds. It follows therefore that the Surveyor has to rely mainly upon his own judgment as to the line of route he is to adopt when going up to the top of ridges and spurs, exceeding 13,000 feet above sea level.

"Accompanying is a statement shewing the amount of work done by the snow party.

"From the two points on the ridge over which the Uttar Dhurra Pass crosses, I obtained a good view of the country to a distance of 12 or 14 miles to the north-west, about 10 miles to the north and a few miles to the north-east. The characteristic features of the whole of this part of the country are precisely the same as those of the northern parts of Ladák. The quantity of snow about it is very small; even at a height of 18,500 feet in many places there is not a vestige to be seen. The spurs and slopes are generally of a soft and undulating character. The only drawbacks to it are its great altitude, the difficulty of moving a survey camp, and the increased contingent expenses that would have to be incurred. It would be better, though not strictly speaking actually necessary, to connect the Níti with the Milam triangulation, but from all I could see, I think the main difficulty in doing so would be found in the neighbourhood of the Níti valley and I am disposed to look upon such a junction as impracticable."

The area topographically surveyed on the scale of 1 inch = 1 mile, comprises 534 square miles and the country triangulated covers 859 square miles. Considering the very unfavorable weather experienced owing to the monsoon setting in so early and that two of the party were inexperienced hands, this out-turn is I think very creditable to Mr. Ryall and the assistants employed under him.

KUMAUN AND GARHWAL SURVEY.

Tabular Statement of out-turn of work, Season 1873-74.

Details of Triangulation.

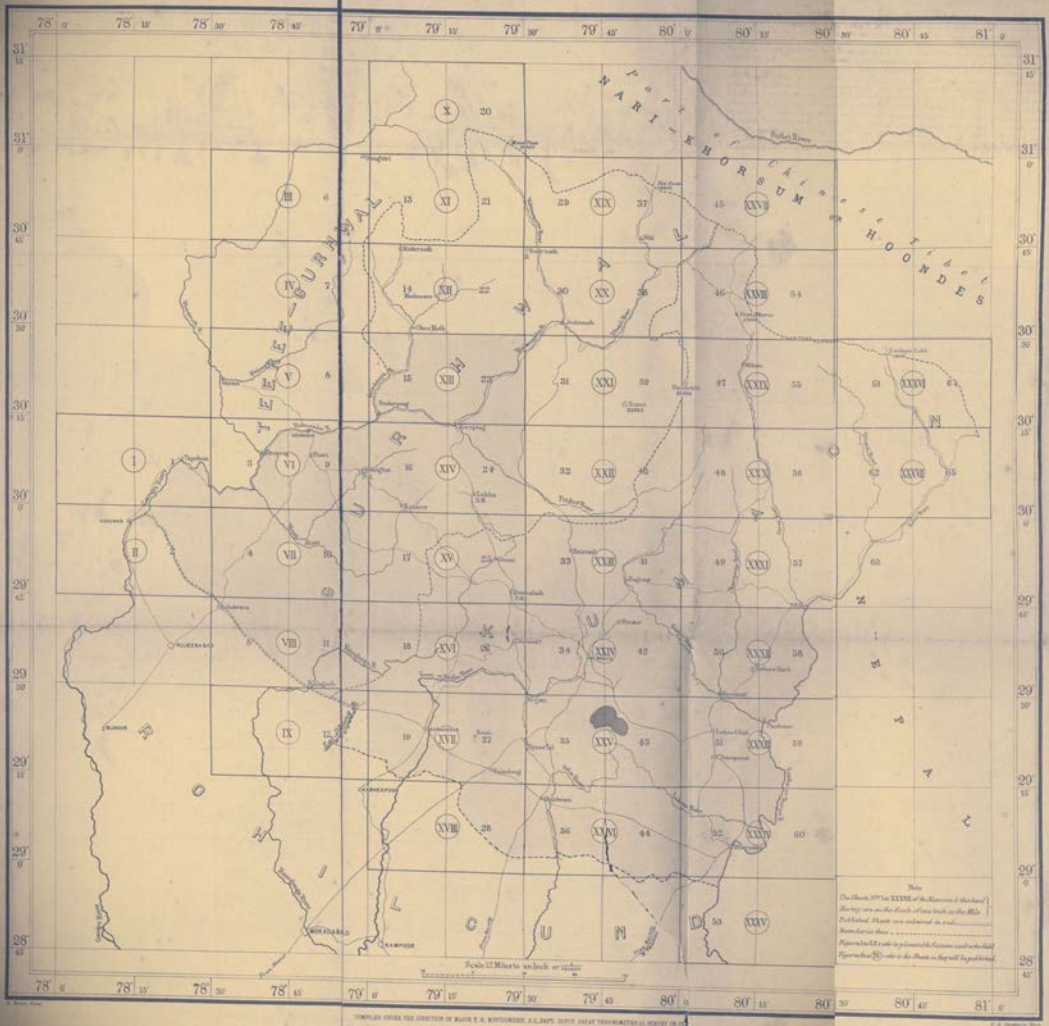
NAMES.	No. of stations visited.	No. of triangles completed.	No. of intersected points fixed.	No. of intersected points of previous triangulation refixed.	No. of points whose heights have been determined.	Area triangulated in square miles.	Average altitude above sea level in feet, of stations visited.
E. C. Ryall, Esq.	14	7	73	0	50	460	15,580
Mr. J. Low, ...	24	22	28	18	70	399	8,452
Totals, ...	38	29	100	18	120	859	

Details of Topography. Scale 1 *inch* = 1 *mile.*

NAMES.	Area in square miles.	Average number of plane-table stations per square mile.
Mr. C. H. McA'Fee, ...	34	0·7
„ E. F. Litchfield, ...	228	0·3
„ I. S. Pocock, ...	149	1·1
„ J. F. McCarthy, ...	123	0·3
Total, ...	534	0·6

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

INDEX TO THE SHEETS OF THE KUMAON AND GURHWAL SURVEY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GURHWAL
KUMAON
NEPAL
CHINA
TIBET
Pari or Lake Manasarowar
NARI-KHORSUM
HOONDES
Sutlej River
Gogra River
Kalee River
Ramganga River
Kosee River
Gurhwal Hills
Kumaon Hills
Nepal Hills
Snowy Range
Kamet
Nundakot
Trisool
Nundadaik
Dhaulagiri
Chowkhumba
Kedarnath
Badrinath
Joshimath
Tapoban
Dhoulee Ganga
Niti Pass
Mana
Bhadrinath
Nitee
Malla Johar
Tola Johar
Milum
Darma
Chaudans
Byans
Dhar Chula
Askote
Pachar
Pyung
Kuthee
Kuthee Pass
Chinee
Jumla
Dotee
Dotee Pass
Kalee Kumaon
Kalee Gurhwal
Tonsa
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Bhageerathee
Bhageerathee Pass
Jumnotree
Gangotree
Gangotree Pass
Kedarkanta
Bunderpoonch
Bunderpoonch Pass
Soomeroo Pass
Soomeroo
Kedarnath
Kedarnath Pass
Chowkhumba
Chowkhumba Pass
Mana
Mana Pass
Badrinath
Badrinath Pass
Nundakot
Nundakot Pass
Trisool
Trisool Pass
Nundadaik
Nundadaik Pass
Dhaulagiri
Dhaulagiri Pass
Kamet
Kamet Pass
Milum
Milum Pass
Darma
Darma Pass
Chaudans
Chaudans Pass
Byans
Byans Pass
Dhar Chula
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Askote
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Pachar
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Dotee Pass
Kalee Kumaon
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Kalee Gurhwal
Kalee Gurhwal Pass
Tonsa
Tonsa Pass
Jumna
Jumna Pass
Bhageerathee
Bhageerathee Pass
Jumnotree
Jumnotree Pass
Gangotree
Gangotree Pass
Kedarkanta
Kedarkanta Pass

Extract from the Narrative Report—dated 30th September 1874—of Captain A. W. BAIRD, R.E., Officiating Deputy Superintendent 3rd Grade, in charge Tidal and Leveling Party.

(1.) My last annual report informed you of all that had been done in altering the Self Registering Tide Gauges for adaptation to any scale required, and that all the instruments, material, &c., for carrying out the operations at the Tidal Observatories were ready for despatch by boat from Bombay.

All instruments &c. ready to be sent off to the Gulf of Kutch.

(2.) A large Puttimar or Buggalow was engaged by the month from the 1st October, and this eventually turned out to be a very economical arrangement. Loading was at once commenced, and although I had relays of coolies, it took 10 days for all the material to be stowed away.

Loading up Puttimar.

(3.) Meanwhile a small boat had been sent off to Gogo from Bombay, with a detachment of the men, to march thence to Wadwán and meet me. Calassies and puttiwallahs had been engaged in Bombay.

Small Puttimar despatched to Gogo.

(4.) Every thing being ready Mr. Bell, Surveyor attached to the Party, and Mr. Peters of the Harbour Defence Works (whose services had been temporarily placed at my disposal by the Government of Bombay) along with 6 Sub-Surveyors and about 24 men embarked in the large Puttimar and sailed on the 13th October for their destination, *viz.*, the site of Okha Tidal Station, opposite the Island of Beyt, at the mouth of the Gulf of Kutch.

Large Puttimar leaves Bombay.

(6.) Having now seen every thing required despatched by boats, and the remaining instruments carefully stored away in the Harbour Defence Workshops, I left Bombay by rail for Wadwán and arrived at Rajkote on the 24th of October.

Remainder of the Party with office stores leaves Bombay for Rajkote.

(8.) I called on the acting Political Agent at Rajkote and arranged several matters with him regarding the assistance I should require from the Native State in whose territories the Tidal Observatories and Bench Marks were to be made. He furnished me with Purwanas, for use in Kattywar.

Arrangement with Political Agent for assistance from Native States.

(10.) Having been joined by the sowars from His Highness the Gaekwar's contingent I marched *vid* Dwarka to Okha Tidal Station, taking with me the chronometers and such instruments as I required, and I arrived at the station on the 21st November.

Leave Rajkote for Okha Tidal Station.

(11.) Captain Jackson, the Assistant Resident at Dwarka, had kindly come out to settle matters on the spot with the native officials of Beyt, so that there might be no delay to the progress of the work: he met me at Aramra about 4 miles from Okha and the nearest village on the main land to the station, and accompanied me to the camp. We found it would be more convenient and economical to get all supplies and even drinking water by boat from the Island of Beyt immediately opposite the station.

The Assistant Resident, Dwarka, visits Okha to arrange for supplies &c. for the camp.

(12.) The Puttimar had arrived safely with Mr. Bell and his detachment all the stores had been landed which were required for this station, and work had been commenced on the 5th November, in sinking the masonry well.

State of affairs on arrival at station.

(14.) The well sinking went on steadily, building up one day and then allowing 2 or 3 days to dry, and excavating inside by Bull's dredgers: 11 feet 9 inches had been completed by the 24th November.

Progress of the well sinking Bull's dredgers used.

(15.) On the days that work had to be stopped at the well to allow the masonry just built to dry the masons were employed in erecting a house for the men who were to be left in charge of the station: the calassies and coolies in bringing stone and mud for this purpose also, and in clearing away the jungle close to the camp.

House for the men at the station constructed.

(16.) We found that Bull's dredgers acted admirably in soft sand, but when we came across any hard strata, then the man standing on the opened bucket, caused it to get a better grip in being lifted up, and so brought up more material; also this man tamped all round with his feet close to the wooden frame as each bucket was taken up, thereby not allowing a deep hole to be excavated in the centre, while the sand remained at its sides: otherwise from the treacherous nature of the ground, a sudden sinking of the well might have occurred, which would undoubtedly have ended in a smash. By the 29th November we had got so far down, that the water inside the well could no longer be kept sufficiently under to allow the man to go down to work and tamping from the top by a long rod was commenced. By the evening of the 29th November 17½ feet had been completed, and 25 feet was the total required. Some rock having been observed cropping up, at low water, a short distance off, I was afraid we might come across it before the proper depth was reached. I had a long iron bar driven

8½ feet below the bottom of the well, by means of a small pile monkey and was glad to find no rock although the sandy strata below was very hard; by the night of the 4th December the whole depth of 25 feet was completed.

(17.) During this time I had taken several observations to stars to rate the chronometers: also I had determined roughly the range of the Tide at Okha to be 14·90 feet at Spring Tides; so as to regulate the scale for working the self registering Tide Gauge; and, I determined by soundings at low water that at 120 feet out, 19 feet of water was found, as I had previously recorded in the last year's reconnaissance and here the rose at the end of the flexible pipe was to be placed.

Rating chronometers. Range of Tide roughly determined.

(18.) The cylinders having been all cleaned out and painted over, inside and outside, with tar, to keep them from rusting, the upright length of small rigid pipe with its bend was attached to the lower length of the cylinder, and 2 other lengths screwed on above. The gyn, tackle, &c., being all in readiness, these three lengths of cylinder were lowered inside the well, and held in suspension, until 2 more lengths were screwed on, and then 2 more making in all 7 lengths or about 29 feet; on lowering we found the whole cylinder floating in the water inside the masonry well, and water had to be poured down inside the cylinder to make it sink. On the 7th December the cylinder was finally placed in position.

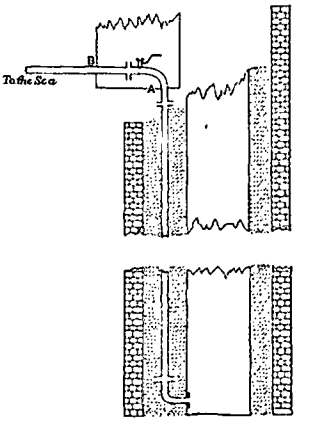
Cylinders placed in position.

(19.) The next thing was to lay out the iron pipes: this was a most tedious operation for the trench had to be of great width on account of the sand falling in constantly at high tide: it must be remembered that in all the operations the amount of plant was limited for we were quite in the jungle and had to use such appliances as were at hand. A wooden frame about 3 feet high and 2 feet wide was inserted in the masonry well for the exit of the iron pipe and stop cock. After keeping all available hands hard at work and the pump going with relays of men, one length of pipe towards the sea was eventually attached on the 10th December—the end of the pipe being carefully plugged up to prevent sand coming in—a thick wall of stone and lime was built all round the stop cock and connected with the masonry well; also a layer of masonry underneath the first length of iron pipe: but still the water percolated in on all sides, and it seemed perfectly hopeless to keep the stop cock dry and to have access to it. The following day the masonry wall was removed and the length of iron pipe disconnected, and two feet added to the height of the vertical pipe and then the bend with the stop cock fitted on.

Iron pipes being laid out from the cylinder.

(20.) A water tight box 3 feet long and about 1 foot square was made in halves and fitted over and under the stop cock, holes having been cut at A and B and carefully caulked up after the box had been fitted over the pipe; in this way no water could get at the stop cock except over the top of the box. Underneath the first 7 or 8 feet of the pipe leading to the sea a layer of mud and stones of considerable thickness was made and a wall of similar material built all round the stop cock leaving a space about 3 feet square in the centre for standing in, and steps for getting down to it, also mud and sand were thrown down between the iron cylinder and the masonry well right up to the level of the stop cock bend: by the 13th December this was completed, and it was found then that the stop cock was quite dry and access could be had to it at any time however high the tide was.

Arrangement for keeping stop cock dry and having access to it at all times.



(21.) Simultaneously with the work at the stop cock the iron pipes were laid out, considerable difficulty being experienced from the sand tumbling in, and by the 15th December 11 lengths had been fitted.

Laying out remainder of iron pipe.

(22.) At the same time that this was being carried out the portable wooden observatory was erected over the cylinder on its piles and cross beams and with a rough masonry platform all round. By the 18th December the observatory was finished and all the fittings placed in it and the aneroid barometer and anemometer set up.

Observatory put in position and fitted up.

(25.) A temporary Tide Gauge was then set up on a pile a little above low water mark, also three Bench-marks were imbedded in masonry platforms at different distances from the observatory: the top of the platform in each case being about 6 inches under ground. Also a pole was fixed by leveling so as to shew to what height the sea had to rise when it would be safe to open the stop cock.

Temporary Tide Gauge set up and 3 Bench Marks built.

(26.) The self registering Tide Gauge was started on a preliminary trial on the 20th December: the float band was altered after one day's work to allow the pencil when near the centre of the barrel to agree with mid tide.

The S.R.T.G. started on a preliminary trial.

(27.) The cylinder had been pumped dry and the stop cock opened and shut several times to try and exclude all the air. The temporary Tide Gauge was connected by leveling with the top of the cylinder for comparison of level of water inside and outside: and after a couple of days' trial it was apparent that air was coming in somewhere in the pipes.

Leakage in pipes discovered.

(28.) The last three lengths of pipes were taken off and the brass connecting piece at the end having been plugged up firmly, the pipes were filled with water, and raised vertically, thus getting a pressure of about an atmosphere and a half, when it was found, that there was a considerable escape between the cast iron flanges and the pipes screwed into them, and also in the brass piece itself water oozed out shewing how badly it had been cast. These three lengths were replaced by others which stood the test, and the brass was hammered where the flaws occurred (as it was imperative to have this part of the system air tight, the other parts being well buried in the sand, or in the water beyond did not require to be so carefully constructed) and the whole relaid again.

Iron pipes tested for leakage.

(29.) The bed plate of the self registering Tide Gauge was connected by leveling with Bench-marks A, B and C, as to this level of the bed plate all measurements for height of water in the cylinder would be referred; and on the evening of the 23rd December every thing seemed to be in good order and ready for the final measurements to be taken, clocks to be rated &c. previous to leaving the station.

Every thing ready for final measurement &c.

(30.) About 3 A. M. on the morning of the 24th December the puttiwallah on duty at the observatory saw a boat which had been sent the previous day to be filled up with stone, drifting down from her anchorage some distance above: he called out lustily to the crew, but they were all asleep: the boat dragged her anchors across the flexible pipe, smashed it in two places, and carried away buoys, anchor, &c., and was brought to near Sainia Island ½ a mile off. After considerable trouble (its anchor having got fixed among some projecting ledges of rock) the boat was taken back and the anchor and buoy with the chain attached were saved but a good deal of the flexible pipe was quite useless. Some of the piping for the other stations was immediately landed and all the necessary repairs effected by the night of the 24th December.

Disaster to flexible pipe.

(31.) Some time before this unfortunate disaster occurred, I had asked the Assistant Resident to warn all boatmen at the different Bunders in Okha Mundel not to come within 100 yards of the red buoy at the Tidal Station. Later on in the season I had printed circulars in Guzerathi issued to all the Durbars for distribution at their different Bunders cautioning all boatmen plying in the Gulf of Kutch not to come near the red buoys at Okha, Nawanár or Hanstal Tidal Stations and the guards at the stations had strict orders to make prisoners of Tindals wilfully infringing these rules: also by your orders I made certain arrangements for protecting the pipe in case any boat should again drag her anchor across the flexible pipe.

Boats warned not to come near the red buoy.

(32.) On the 25th and 26th December comparisons were made to compare the level of the sea water outside, as indicated by the temporary Tide Gauge with that of the water in the cylinder: and they were found to agree exactly. The clocks of the self registering Tide Gauge and aneroid barometer were rated many times and the pendulum of each altered as necessary till they appeared to be going very well: the anemometer clock was apparently going in pretty good time.

Measurement made for connecting position of pencil on S.R.T.G. and distance of water from Bed plate—Rating clocks &c. &c. Temporary Tide Gauge comparison.

Measurements were taken at both rising and falling tides to determine the distance of the water in the cylinder from the bed plate which agreed with the pencil being on the central line of the barrel, and from which of course the corresponding depth for the zero line could be deduced. The measurements were made very exactly by means of a tape to the end of which was attached a flat piece of wood about 4 inches square with a thin cake of lead 2 inches square fitted to its centre. At the instant of contact with the water, the position of the pencil was marked on the barrel and the depth from the bed plate recorded to the $\frac{1}{40}$ of an inch: and the distance on either side of the central line of the barrel also taken to the $\frac{1}{40}$ part of an inch. This was repeated about 20 times and the mean value of the set taken as the value for the rising or falling tide as the case happened.

(34.) On the 23rd December I sent off Nursing Dass, Sub-Surveyor, to lay down Bench-marks and Pillars, one at about every 10 miles from Okha Tidal Station along the road to Hanstal and thence to Nawanár in Kutch across the Runn. I had ordered him to lay down these Bench-marks also with reference to the nearest G. T. Stations.

Sub-Surveyor sent off to lay down Bench-marks and Pillars.

(35.) A guard of 4 Sepoys and 1 Naique was supplied from the Battalion of His Highness the Gaekwar, for the protection of the Station—their duties being principally to see that no boat came near the buoy, so far as they could prevent it. Three post runners were engaged for carrying the letters to and from Dwarka (the nearest Post Office) and by this means I could receive a daily report of the working of the station which the Sub-Surveyors had to fill in from the printed forms supplied them. The food for the men of the station was to be sent 2 or 3 times a month from Beyt: the Thanadar was responsible for this, and their drinking water (as the number of men including the guard was now only 9) could be procured from a well about a mile and half off; coolies being engaged twice a month to fill an iron water tank left at the station for this purpose.

Guard, Post runners, Supplies, &c., for the Tidal Station.

(36.) Every thing being now apparently in good working order and a supply of stones filled up in one of the boats, the party embarked on the afternoon of the 27th December for Hanstal.

Embark for Hanstal Tidal Station.

(37.) I shall now describe the Okha station as left on the 27th December 1873. The observatory is situated on the shore of the Okha Mandal mainland almost exactly opposite the town and island of Beyt, about 300 yards south of the northeastern corner of the land, and which is called "Okha Point" in some old charts. The flag of the principal temple of Beyt has a bearing of 151° from the observatory; the pole in the temple on Sainia island bears 7° 30′. The latitude as deduced from G. T. Survey triangulation charts is 22° 28′ 11″ N. nearly, and longitude 69° 7′ 0″ E.

General Position.

(38.) The observatory is a wooden erection constructed so as to be easily taken to pieces and fixed on three cross beams fitted on the tops of 6 large piles imbedded 8 feet in the sand. A brick masonry well 4 feet in diameter was sunk to a depth of 5 or 6 feet below low water springs, the sand excavated at the bottom being very hard and to all appearances in close proximity to rock. Seven lengths of cylinder each about 4 feet 2 inches long, and composed of wrought iron, with cast iron flanges carefully faced by turning, so as to fit exactly, were connected together by bolts and nuts so as to be perfectly water tight and lowered inside this well. The interior diameter of the cylinder was 22 inches—the level of the top-flange being about 6 feet above high water spring tide, and about 2 feet 6 inches above the floor of the observatory—a board fitted on and screwed to the top of the cylinder, with holes for the float band to pass through, prevented any thing falling accidentally inside the cylinder.

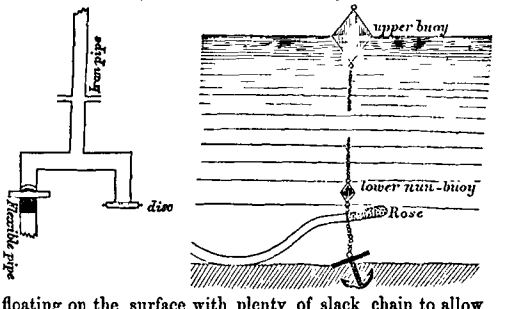
The observatory, cylinder, &c.

(39.) Nine inches from the bottom of the cylinder a 2-inch iron pipe was taken up vertically being connected by a small bend and carried up to within 12 feet 6 inches of the top of the cylinder where there is another bend with a stop cock fitted into it. This 2-inch iron pipe in lengths of about 14 feet with cast iron flanges at each end was then taken out (having a slight inclination downwards) until it met the natural surface of the sand close to low water mark, and this pipe was extended till nearly two lengths appeared to be under water at even the lowest springs, the total length from the cylinder being 175 feet.

Iron pipe from cylinder to low water mark.

(40.) At the end of the rigid iron pipe a brass connecting piece, made as shewn in the sketch, was fitted, having two outer extremities, to one of which a flexible 2-inch suction pipe was fixed and the other closed by a brass disc with a good washer. Two lengths of this suction pipe were taken out to deep water: at the end of the outer length a copper rose of about 15 inches length 2 inches diameter and having about 150 holes bored in it was screwed on. This rose was sustained about 6 feet from the bottom, being attached to a small nun-buoy by a chain and shackle with swivel, the whole being held in position in deep water at a place where there is nearly 20 feet of water at low springs by an anchor. To the top of this small nun-buoy a chain was attached, to which was fixed the large buoy floating on the surface with plenty of slack chain to allow for rise and fall of tide, and this buoy also marks the position of the flexible pipe.

Brass connecting piece and flexible pipe.



(41.) The observatory is about 12 feet × 9 feet × 9 feet, the cylinder being about 2 feet from the eastern end: the self registering Tide Gauge being of course as nearly as possible in the centre of the building. The aneroid barometer is placed carefully on a shelf on one corner. The ane-

Interior of observatory and fittings.

mometer is fixed to a shelf so that the upright pipe passes through the roof close to the ridge at the western end (the Rain Gauge being close to it on the outside). A platform was made to get at the anemometer easily and this served a double purpose, as it was also the framework for a guard to protect the pendulum, and clock of the S. R. T. G., and cloth having been fixed all round it kept any wind from getting to the pendulum. Steps were fixed, convenient for access to the platform. A long box to keep the S. R. T. G. papers on a roller preparatory to putting them on the barrel and which also held diagrams for the other instruments, &c. Also a table made expressly for size to suit the S. R. T. G. sheets being prepared, were placed on one side of the observatory.

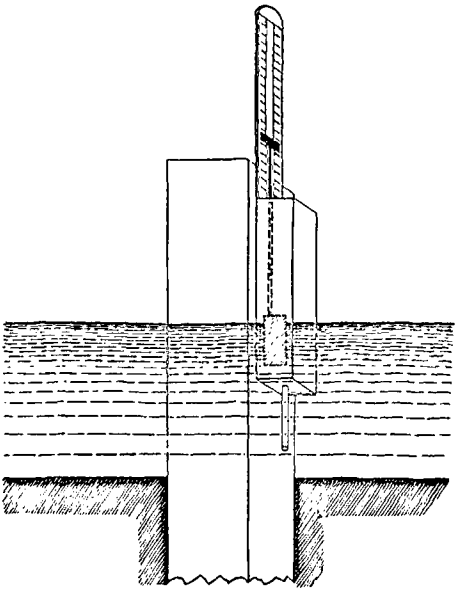
S. R. T. G. in position.

(44.) The self registering Tide Gauge was carefully put in its position, so that the band allowed the float to be 3 inches from one side of the cylinder, while it was the same distance itself from the other side. The instrument having been carefully leveled by wedges, the trestle was secured with screws to the floor; a hole was cut in the floor and a small box let down (properly fitted so as to allow no sand to come in) in order that the counterpoise weight might be able to act for the entire range of the instrument.

The float band was made 35 feet 6 inches long and 33 feet of chain was added to this, and fixed at its other end to the hook under the float, forming a continuous band as it were. The scale of wheels adopted here is $\frac{1}{4}$, the barrel being 5 feet long, that scale was the largest that could be used for a 14·90 feet range of tide. The float has a swivel to which the band is attached, and the band also passes through 2 guides fixed to an upright scale on one side, and through another guide fixed to the trestle on the other.

Temporary Tide Gauge.

(48.) The temporary Tide Gauge, consisting of a pile firmly imbedded in the sand and standing about 8 feet out of the ground, was placed about the level of low water neaps; to this was attached a box containing a copper float, and a deal rod was attached to it with a pointer about 6½ feet above the float. The box has a bottom to which is attached a pipe (2 feet long) of small diameter, by means of which the sea has access to the float; the box itself is about 6 inches square and 6 feet high: the back of it, *viz.*, that side attached to the pile was 12 feet long and has a groove in which the upright rod with the index works (*vide* sketch) so that by having this upper part numbered from a certain zero the level of the sea below this zero could be at once read off. It was found by careful trial in a bucket of water that the pointer always recorded 6 feet 2 inches above the level of the water in which the float worked—the scale was made accordingly: levels were taken to connect the temporary Tide Gauge with the top of the cylinder, for comparison of level of water inside and outside.



Voyage to Hansta Tidal Station; Puttimar stuck on sand bank.

(50.) The Puttimar and other boat weighed anchor on the afternoon of the 27th December but we had to anchor again off the town of Beyt on account of the tide and remain for the night. On the morning of the 28th we again set sail having a pilot on board the large boat; after being about half an hour or so under full sail with a stiff breeze, we struck on a sand bank, and heeled over tremendously and then stuck. The tide was falling at the time. On this occasion Mr. Peters' services were invaluable, he at once assumed charge of the vessel and ordered the Nacoda and his men to do what he thought necessary for the safety of the vessel. Heavy spars were lashed vertically to the sides of the Puttimar to prevent it capsizing as the tide fell, and after some considerable delay on the part of the native officials at Beyt,

assistance in the shape of some small boats was sent to us but I must here record that it would have fared very badly with ourselves, the men of the party and the Government stores had not Mr. Peters used prompt measures and taken the command of the vessel out of the hands of the Nacoda. A new pilot was obtained from Beyt, and when the boat righted itself in the high tide in the evening we got her out into deep water.

Masonry well not required at Hanstal. Excavating hole for the cylinder.

(54.) The ground at Hanstal being black soil, the surface of which was covered by about one inch to one foot of water, at extraordinary high tides, for miles in land, it was of course unnecessary to sink a masonry well, if we could excavate a hole deep enough for the cylinder. This excavation was begun about 30 feet in land from the usual high water line of spring tides, and by the 14th January 16 feet had been finished. After this however it was evident from the sides falling in that we were excavating too perpendicularly, and from the proximity to the water of the creek that a good deal of surface water came in; on the 23rd I abandoned this site and went in land about 150 feet and commenced the excavation.

(56.) By making the excavation of considerable diameter and with a pretty gentle slope, in 4 days we had got to the depth required, *viz.*, 25½ feet; all available hands, coolies, calassies and peons, were kept at this work, and from early morning till dark, because the longer it took there was more chance of the gradual surface drainage carrying down the sides.

Cylinder placed in position.

(57.) The iron cylinder was lowered into the hole much in the same way as had been done at Okha Tidal Station.

Bench-marks and pillars constructed also house for men.

(58.) Three Bench-marks, near one of which a pillar was made, were built similarly to those at Okha Tidal Station at different distances from the cylinder: also a house for the men was constructed.

Observatory placed in position on its cross beams and piles and pipe being carried out.

(59.) The Observatory was next fitted up and placed on its cross beams and piles: steps and side retaining walls having been constructed to have access to the stop cock. Here it was not necessary to contend against the water percolating in to the same extent as at Okha where the foreshore was simply sand. A small box was fitted over the stop cock bend as before and a layer of stone and some cement prevented any great accumulation of water. A temporary Tide Gauge was placed here as at Okha.

Watchmaker called up from Bombay.

(61.) Some time before this one of the reports from Okha Tidal Station brought me information of the entire stoppage of the anemometer clock at that station; some of the wheels having become broken. Finding all the self registering Tide Gauge clocks dirty and that the anemometer clocks wanted generally to be looked at, I found it necessary to get up a first rate watchmaker from Bombay at once; I kept him hard at work at Hanstal overhauling all the clocks until the station was completed, and then took him on to Okha to repair the damage there.

It was most fortunate I made this arrangement when I did, for he found that the clock of No. 7 Tide Gauge (*viz.* one of the escapement balance clocks) was quite unfit for work, some of the teeth having been quite worn away: the weight he considered far too heavy. Also all the anemometer clocks had to be carefully cleaned up, for as you will recollect, gold springs had only just been received for them a day or two before I left Bombay and they had been rather hastily put in. I found this Parsee watchmaker a very good workman indeed, and we could not have got on without having all the clocks in good working order.

Back-lash weight to overcome the instrumental error in the S.R.T.G.

(62.) As I have already stated I found that there was a great instrumental error in the self registering Tide Gauge, on account of the large amount of back-lash between the wheels attached to the diagram barrel and those of the clock. *By a very simple plan I succeeded in quite getting rid of this error and thereby adding very greatly to the value of the performances of the instruments.* A small pulley was attached to the trestle by a piece of wood some 6 inches long; a piece of cat-gut cord fastened by a hook at one end to the clip which held on the paper on the diagram and wound round the barrel, passed over this grooved pulley and had a weight fixed to its other end. In this manner the barrel was always being drawn round, and back-lash was effectually destroyed; not only that, but this weight acted as a maintaining power, when the clock was being wound up. The weight had to be disconnected, and the cord re-wound round the barrel once a day, and it was so arranged that there was a free fall of quite enough length for 30 hours.

General position.

(68.) Hanstal Tidal Station is situated on the Kattywar side of the Hanstal creek, about ¼ of a mile from its mouth. The foreshore at the station runs nearly east and west, and, at about ¼ of a mile from where the creek joins the gulf, it bends round to a north and south direction. The opposite shore is part of the Runn of Kutch and is a mud flat covered with mangrove bushes. The creek at the station is about 2 miles broad. The whole plain between the station at Júria is perfectly flat, without a tree or bush to break the monotony of this Runn, and which has not even a blade of grass growing on it. At extraordinary high tide in the monsoon it is covered with about one foot (in some parts) of sea water. The only thing to mark the site of the observa-

tory except what has now been made being a Mussulman's "pír" about ¼ of a mile to the west: this pír is a pole stuck into the ground, with a few dirty rags attached to it, and some half dozen stones piled up close to it, to mark the site of some Mussulman's grave. Approximate Latitude of the station 22° 55′ 20″ N. and Longitude 70° 23 0″ E.

Water tanks, Guard and Post runners.

(81.) Four iron tanks and 12 casks were left for the water supply and a contract was made with the former boatmen to carry water twice a month for the station, taking out at the same time a Banyá with supplies of food for the men, all from Júria about 25 miles off. A guard of 1 Náik and 3 Sepoys was sent by His Highness the Jam of Nawanagar, and 3 Post runners (old men of the Postal Department) were engaged to carry the letters to and from Júria Post Office. The site of the station had formerly been that of a Postal Chauki when that was the route to Kutch.

Detachment of the Party proceeds to Okha and remainder to Nawanár to start work.

(82.) Hanstal Tidal Station being now fairly established, I proceeded with a few of the men (taking also the watchmaker with me) to Okha Tidal Station to repair the damage to the anemometer clock. I arrived there on the 27th February. The remainder of the party in charge of Sub-Surveyor Nursing Dass and accompanied by Mr. Peters proceeded direct to Nawanár where they arrived on the 24th February.

Disappearance of the upper buoy at high water. Breakage of flexible pipe.

(85.) The Sub-Surveyor in charge having reported that from the 20th January the upper buoy was not seen at high water, arrangements were made by means of a small boat from Beyt to get the anchor, &c., up and see what was the matter. The chain attached to the upper buoy was found wound round and round the anchor, and the flexible pipe had been partially broken at a distance of 40 feet from the brass connecting piece; and we could not get this part of the pipe in, as it was buried so deeply in the sand under water. All our appliances for effecting repairs, &c., had been sent on to Nawanár and as the neap tides were coming on and the damage to the pipe could not be properly put right, until we took up the last rigid pipe and brass connecting piece, I determined to get some men and the mechanics across from Nawanár and effect the necessary repairs about the 18th March when we would have the spring tides.

Repair to piping effected at Okha Tidal Station and everything left in good working order

(88.) Mr. Peters and his men having arrived from Nawanár on the 18th March (the low tide favouring the work) the last 3 lengths of the iron pipe and brass connecting piece were taken up: but the flexible pipe broke off at 4 feet from the end, and the remainder it was found impossible to save, so deeply was it buried in the sand. The following day the flexible pipe was repaired and strengthened, and a new piece added, making a total of 99 feet: two stout coir ropes were taken along the entire length of the pipe, and secured by coir lashings, the pipe being slack, and ropes taut, also at each end a service of 4 or 5 feet of thin coir line was made, to prevent rubbing, and generally to strengthen these parts. The pipe was re-laid on the 20th March and the upper buoy was done away with; the chain attached to the anchor was brought in shore, and a strong rope attached to it was secured to the foot of the temporary Tide Gauge, so that the anchor might be raised at any time required. The stop cock was opened and every thing seen to be in good order. Mr. Peters and his men returned to Nawanár while I remained to take some measurements and comparisons at the station. All the clocks having been rated and apparently going very well, and the comparison of the water in the cylinder and temporary Tide Gauge being satisfactory, measurements at rising and falling tides for determining position to correspond with zero of gauge, having been taken, &c., I left by boat for Nawanár Tidal Station which I reached on the 29th March.

General position.

(99.) The Station of Nawanár is situated on the western shore of the creek of that name just at the end of the spit of sand as the creek joins the foreshore of the gulf. Approximate Latitude 22° 44′ 20″ N. and Longitude 69° 45′ 10″ E.

The observatory, cylinder and pipe.

(100.) The Observatory is similar to those at Okha and Hanstal and is placed so that its length runs nearly east and west, the anemometer being fixed at the westerly end. The masonry well for the cylinder was sunk to a depth of 23 feet below high water springs, and ordinary high water mark just reached the site of the Observatory. The vertical pipe came up to about 14½ feet from the bottom and then the stopcock bend was fixed and 16 lengths of iron pipe taken out with a gentle decline down to low water spring tides, and the pipe packed up with large stones here and there to prevent settlement. The brass connecting piece was fixed at the end and placed in 3 feet of water at low spring tides, being secured in position by stakes and lashings.

Flexible pipe.

(101.) The flexible pipe was carefully parcelled through its entire length, and two strong longitudinal ropes secured to it, at intervals of 2 feet, and firmly joined to the iron pipe, and when taken out the rose was lowered at about 100 feet from the end of the iron pipe: the buoy sustaining the rose similar to Okha, and the chain for raising up the anchor taken in shore and attached to the temporary Tide Gauge by a stout rope; this was afterwards attached to one of the hawsers, in connection with the large buoy.

(109.) I left Nawanár Tidal Station with a detachment of the Party on the 26th April to sail direct for Okha Tidal Station; but at this season of the year the wind blows almost directly down the gulf, and we had to make for Serráyá Bunder on the Kattywar coast and march thence to Okha. Mr. Peters with the remainder of the men sailed for Mandavie to purchase large coir rope or hawsers; after being nearly wrecked, he reached Mandavie and got the necessary supply of rope and crossed to Okha Tidal Station. The Observatory was inspected, clocks corrected &c., while the heavy anchor and large buoy, side hawsers and piles were being laid down. Mr. Rendell and Mr. Peters then left by boat for Hanstal on 3rd May; passing Nawanár, the hawsers were laid down as at Okha; and they reached Hanstal on 6th May. Here it was found that the hawsers (strong though they were) would not stand the drag of the buoy from the enormous current down the Hanstal creek, so both were put on the same side of the pipe, *viz.*, the side nearest the gulf, as it was considered that boats would not be able to make for the station on the other side.

Okha Tidal Station buoy, anchor and guy hawsers laid down &c. Hawsers at Hanstal.

(110.) All the work having been completed Mr. Peters and the men temporarily engaged left Júria for Wadwán and Bombay on 13th May. I reported very favourably on Mr. Peters to Major Merewether as he was most energetic in the performance of his duties and always worked most willingly often at night long after usual working hours and on Sundays when emergencies required it. Mr. Peters had sent all the blocks, pump, &c., lent me from the Harbour Defences, back by steamer to Bombay some time before.

Mr. Peters leaves for Bombay.

(111.) The stations being now all fairly established and apparently working well, the remainder of the field season was occupied in inspecting them as required.

General work of the Party after the stations had been established.

(112.) Nursing Dass left Nawanár Tidal Station on the 15th April to complete laying down the chain of Bench-marks from that station round to where he had left off on the Kattywar side. The line crosses the Runn of Kutch between Shikárpúr on the Kutch coast, and Mallia on the Kattywar coast. Two Bench-marks were laid down actually in the Runn, on which at the time there was about one foot of water, but he was told by the people at these places that in the months November to February this route is quite dry and carts pass backwards and forwards. The total number of Bench-marks laid down was 38.

All Bench-marks from Okha to Nawanár laid down.

(113.) All spare stores having been collected and placed in a large room in one of the towers of the wall at Júria, I moved into Rajkote with the Party on the 10th June. Mr. Rendell however was still in the field inspecting the station at Okha. He reached Rajkote on the 1st July with the rest of the men.

The Party move into recess quarters at Rajkote.

(114.) I had about this time a great deal of correspondence with the Political Agent in Kutch and the Assistant Political Agent in charge of Hallar, Kattywar, relative to the site of Hanstal Tidal Station, although I avoided doing any thing which might bring about Political complications, yet the fact of the Tidal Observatory being erected at Hanstal seemed to be the occasion for the Durbárs of Kutch and Nawanagar to raise the question of right to the ground on which it was situated. I supplied both the Political officers with a rough sketch of the ground in the immediate vicinity of the station; but the line of demarcation between the two States seems to be very indefinite; and as His Highness the Rao of Kutch is the sovereign of the waters of the gulf, his claim is that all the ground up to high water mark belongs to him; and as this claim if held in its entirety would be tantamount to the whole of the ground, covered by any extraordinary high water during the monsoon, coming under the jurisdiction of His Highness of Kutch, the Durbár of Nawanagar disallow it, and I believe the matter is to be referred to Government for decision.

Political complications regarding Hanstal Tidal Station.

(115.) About the beginning of May the Sub-Surveyor at Hanstal reported that 2 native vessels came and anchored near the Observatory at Hanstal; the men who said they belonged to Kutch landed from the boats, most of them being armed; there was some altercation between them and the guard of the station and eventually a spear was taken from one of the Kutch men: after a short time they re-embarked and set sail. It would appear this was the second time something of the kind happened. Shortly after I had received this information, I had copies of letters sent by the Durbár of Kutch to the Political Agent, stating their case, and requesting me to order the guard at Hanstal not to interfere with their men; also copies of letters from the Nawanagar Durbár to the Political Agent in Kattywar, stating that unless he interfered, there was likely to be a fight between the Kutch men and the guard at Hanstal. On receiving these documents I addressed the Political Agent in Kutch requesting him to allow matters to rest as they were until the work at the station was finished, and that as a tentative measure the guard and supplies for the station should be continued from the Nawanagar State.

Boat with armed men from Kutch landed at the Hanstal Tidal Station and gave some trouble.

(116.) Very little work could be done in office during the recess: Mr. Rendell had gone on two months' privilege leave from the 3rd July. I had only Sub-Surveyor Nursing Dass to assist me, also I had to visit the Tidal Observatories and inspect the work there. Bad accounts from Nawanár Tidal Station were received about the end of June which made it imperative for me to visit that station as soon as possible. The inspection of the Observatories during the monsoon entailed a good deal of exposure and discomfort, by having to make long marches in the rain. I was actually in the field 38 days between the 7th July and 8th September and had marched nearly 800 miles in that time.

Work in Office during the recess. Mr. Rendell takes privilege leave. Inspection of stations during the monsoon.

(117.) Fifty-five sets of observations to stars have been made and computed for rating the chronometers from time to time in the past year. During the monsoon there were very few nights of course in which I could observe. As a rule I managed to rate the clocks previous to leaving for a tour of inspection and immediately on returning. In this way a very exact value of the time could be obtained in rating the observatory clocks, and for final corrections for the diagram of the self registering Tide Gauge sheets.

Star observations for rating chronometers.

(169.) Mr. T. H. Rendell, Assistant Surveyor, was transferred from the Kattywar Party in March last; I have every reason to be satisfied with the way he has performed his duties. I have also to state that from the interest he takes in the work and his mechanical turn he will be particularly useful in this party. Mr. Rendell had two months' privilege leave during the monsoon, and this tied me down very much as I had to take up all the inspection duties and during the most inclement season of the year for travelling.

Personnel of the Party.

Nursing Dass, Sub-Surveyor, has been most useful to me in every way; he is sharp, and hardworking, and I quite endorse the character given him by the officer under whom he served previously to joining this Party. I hope you will record his name, for promotion to a higher scale of pay on the first opportunity.

With regard to the Sub-Surveyors at the stations, they have all done their duties remarkably well. Although the work at Nawanár has been almost entirely stopped during the monsoon, yet the Sub-Surveyor in charge there has shewn on several occasions a particular aptitude for overcoming any difficulty which presented itself, that Mr. Rendell having reported very favorably on him, I took the opportunity of informing all the Sub-Surveyors at the stations that I should bring the names of those men who proved themselves hardworking and intelligent prominently to your notice at the end of the operations.

(171.) In conclusion I have great pleasure in recording the courteous assistance given me by Captain Jackson the Assistant Resident at Dwarka, during the time Okha Tidal Station was being constructed, and since then, while work has been carried on there.

Assistance from Political Officers.

My acknowledgements are equally due to Captain Goodfellow the acting Political Agent in Kutch for the assistance rendered me at Nawanár. To Colonel W. W. Anderson the Political Agent in Kattywar and the Assistant Political Agent in charge Hallar; I am also greatly indebted for their kind assistance on many occasions: I have to thank the latter officer especially, for more than once, having so strongly represented matters to the Durbár of His Highness the Jam of Nawanagar, that the difficulties arising from the native officials at Júria being careless and dilatory in looking after the supplies for Hanstal Tidal Station, were always overcome, otherwise, there would in all probability have been a cessation of work at that station from the men in charge being actually without food or drinking water.

Extract from the Narrative Report—dated 3rd November 1874—of CAPTAIN W. J. HEAVISIDE, R.E., Deputy Superintendent 3rd Grade, in charge of the Pendulum Operations.

(1.) No report was submitted by me last year. This was partly due to the fact that the party had no recess; and partly because I considered that an account of the operations undertaken for the completion of the Pendulum experiments could more satisfactorily be embodied in one report. I must therefore now go back to the autumn of 1872; when, having previously gone through a course of practice, I commenced my first series of regular pendulum observations.

(2.) This series was taken at Mussoorie in October 1872, just after the break up of the monsoon. The pendulums were swung at the full atmospheric pressure in order that the results might be directly comparable with those obtained there from Captain Basevi's observations in 1866. The results were as follows:—

TABLE OF THE RESULTS.

OBSERVERS.	Number of vibrations in a mean solar day, reduced to an infinitely small arc to a temperature of 72° F. to a vacuum but not to mean sea level.		Means of both Pendulums.
	Pendulum No. 1821.	Pendulum No. 4.	
Captain Basevi, ...	85956·09	86056·77	86006·43
„ Heaviside, ...	85956·16	86056·54	86006·35

(4.) On the 30th of October the party went down to Dehra. From that time till the middle of January, I was engaged in a series of preliminary experiments with the Russian Pendulums of which I had no previous experience.

Separate reports will be submitted, both on the operations with the Russian Pendulums, and also on those with Kater's Pendulum; consequently details of the work done with those pendulums will not be found in this report.

(5.) On the 21st of January 1873, I left Dehra for Kaliána, which is the base station for pendulum experiments in India. Mr. Macdougall had already been sent to Kaliána with the invariable pendulums and apparatus, with instructions to make the necessary preparations there, for a series of observations, both with the invariable pendulums and with the Russian pendulums. After completing this work, he was relieved by Mr. Keelan and returned to Dehra, so that he might march out again to Kaliána in charge of the Russian pendulum apparatus. This change of duties was necessary, in order that Mr. Keelan might be present at Kaliána when I commenced to put together the invariable pendulum apparatus. Mr. Keelan had not previously seen this apparatus, and as he was to accompany me to England as sole assistant, it was requisite that he should have as much instruction in the matter as possible.

(6.) Although the results obtained with the invariable pendulums at Mussoorie, were sufficient to show that the pendulums had undergone no sensible changes in their travels to Thibet and back; yet it was considered advisable to compare my results with Captain Basevi's still further. A short series of observations was therefore taken with these pendulums at Kaliána at a reduced pressure, during the course of the operations with the Russian pendulums. Comparing my results with those taken in 1866 by Captain Basevi I find

For Pendulum.	1866-1873.	Mean difference.
No. 1821	— 0·060 vibrations	
No. 4	+ 0·108 „	+ 0·024 vibrations

(7.) The party left Kaliána on the 10th of March and marched into Muzaffarnagar. Such of the instruments and equipage as I considered it necessary to take with me, were carefully packed in my presence in a railway goods van, which was then locked up and despatched through to Bombay. With the exception of 8 men whom I took to Bombay with me, the native establishment was paid up and dismissed. Mr. Macdougall then returned to Dehra in accordance with your orders, taking with him the instruments and stores I did not require. During the time Mr. Macdougall was with me, he showed himself industrious, willing and most zealous in his duties; but in order to become a valuable assistant he must endeavour to acquire greater accuracy in his work.

(8.) On the 15th of March I reached Bombay. Mr. Keelan who brought down the natives and broke the journey at two places, *en route*, arrived there on the 19th instant. On the 20th the instruments and stores were moved over to the Colaba Observatory.

(9.) Mr. C. Chambers, the Superintendent, placed at my disposal an out-building in the Colaba Observatory compound, which was well suited for the experiments. The building was 40 feet long, by 30 feet wide, with a solid stone floor, stone walls, and a tiled roof. Inside this again uprights supported the roof and formed an interior space of 24 feet × 14½ ft. This space was enclosed with bamboo matting and within it the pendulums were swung. The objection to the building was its propinquity to the main road of Colaba from which the outer wall of the building was but 8 feet distant. Although the pendulums were swung on isolated pillars, yet

it was considered advisable to guard still farther against the vibrations caused by passing vehicles. For this purpose the road was thickly covered for some distance with small bundles of straw laid close together. The construction of the building rendered it necessary to suspend the Shelton clock from a wooden framework which was made for the purpose in Bombay. Owing either to this method of suspension, or to the clock not being on an isolated pillar; the clock, which generally goes very well, had at Colaba, a comparatively irregular rate. The effects of this on the observations, were it is considered, almost entirely eliminated by comparing the clock Shelton at short intervals with the Observatory clock (by Thwaites and Reed) the rate of which was very constant and well known. These comparisons were made twice a day near the commencement, and near the end of each set of pendulum observations.

(10.) I am deeply indebted to Mr. C. Chambers both for the assistance he afforded me in my work at Colaba, and also for his hospitality. I had been in correspondence with him on the subject of the preparations which were required for the experiments, and on my arrival at Colaba I found that the building had been so carefully and efficiently prepared, that it only remained for me to put up the apparatus. Isolated pillars had been built, the observing pit dug, and the roof, doors, windows and interior space covered in with matting. so that the temperature might be kept as equable as possible. A wooden frame had also been prepared for the clock, from a design I had sent. Transit observations were usually taken at the Observatory 3 times a week. But Mr. Chambers kindly arranged to have them taken every night (Sundays excepted) during my pendulum observations. Thus the Observatory clock which was by Thwaites and Reed, and had a very good rate, became a standard with which I could compare my clocks at any time.

(11.) When I had got the vacuum apparatus together and began to pump, a bad leak showed itself. After some time the leak was traced to one of the windows. I therefore took down the cylinder and overhauled it thoroughly. The windows were repacked, and the whole cylinder repainted. This took some time but was a most successful job, as I had no further symptoms of a leak up to the conclusion of the work at Kew.

(12.) After the quiet of Kaliána the noises at Colaba were most distracting. Carriages and people were constantly passing along the road. Occasionally there would be a shout of Ho! Ram Bak-ash! Ram Bak-ash! Ho!! the prelude to a conversation between two natives carried on at a distance perhaps of 200 yards. The ladies of Colaba too, were it seemed to me the most indefatigable musicians, and at first I was sometimes puzzled to determine whether I had compared the clock with a beat of the chronometer or with a note from Semiramide. I was lucky however to arrive at Colaba just at the conclusion of the annual artillery practice, which goes on at a battery just below the Observatory, and which might otherwise have necessitated a change of hours, for swinging the pendulums.

I have since had a good deal of practice in observing amidst noises, and any thing moderate does not annoy me. But I had not realized before, the enormous advantages we Surveyors enjoy in India at our stations, remote from such distracting causes.

(13.) The observations at Bombay were finished on the 18th April, and in accordance with your orders the party was transferred to Lieutenant A. W. Baird, R. E., Assistant Superintendent in charge of the Tidal operations.

At Bombay I engaged a Tindal and 12 Lascars to accompany me as far as Egypt. It was some time before I could find a good Tindal, who was willing to collect the lascars, and trust himself with me. But at length I obtained the services of one, Sheikh Daod. This man and the lascars he brought, turned out treasures. At Bombay they learnt their duties in the Observatory in a few days: their knowledge of ship board, and the assistance they rendered in shipping and unshipping the instruments were most valuable to me; and they gave me no trouble either in their conduct or with complaints about food &c. They were expensive certainly but well worth the money. I have never before met with natives so intelligent and enterprising as these men were. When the work was finished in Egypt and I was sending them back to Suez, it was with some difficulty that I persuaded them to relinquish a plan they had formed of going to see Cairo.

(14.) Mr. Keelan left Bombay on the 21st of April. I gave him a letter to Lieut. Colonel Goodfellow, R.E. who was in charge of the military works at Aden and he very kindly placed some workmen at Mr. Keelan's disposal, to build the transit pillar and make other preparations necessary for the observations there.

(15.) I did not leave Bombay until the 28th of April. The interval between the 19th and 26th was fully occupied in carefully packing every thing, and in making arrangements for shipping the instruments. The Peninsular and Oriental Company's steamers were very much crowded at that time of the year; but nevertheless Mr. Parker, the Assistant Agent, kindly gave me a place for the instruments in one of the mail rooms. I may here state that my best thanks are due to the Company's Agents at Bombay, at Aden, at Suez, and at Alexandria; as also to the officers of the steam ships Deccan, Nubia and Candia who did every thing in their power to assist me in shipping and unshipping the instruments, and in stowing them carefully in safe places. It is chiefly due to them that all the instruments travelled from Bombay to Kew without receiving the slightest damage, and even the Syphon Barometer when compared at

Kew was found to be free from error. Mercurial Barometers are proverbial for getting out of order in travelling. This one was so fortunate as to travel with Captain Basevi into Thibet; to return thence, and to be used by me at all the places at which I observed between Bombay and Kew, where it arrived in good order. A description of it may therefore prove interesting.

(16.) It is a Syphon Barometer of the Gay Lussac principle.

The glass tube is tied down to a strip of wood, on which a paper scale is pasted. The scale is graduated to tenths of inches, and the readings are taken with the assistance of a detached sliding vernier. Three or four small pieces of cork are inserted between the tube and the scale. The strip of wood is screwed down at the two extremities inside half a bamboo, through each end of which a string passes to suspend the barometer by. When travelling, the barometer is inverted; the other half of the bamboo fits on as a cover, and the whole is secured at the ends by two leather caps connected with straps, one of which is long enough to allow the bamboo to be carried over a man's shoulder. This barometer has probably remained in good order so long, because, with the exception of two screws and the mercury, there is nothing metallic about it.

To preserve the knife edges of the pendulums from rust, on board ship, I first oiled them well. I then rubbed off the oil with a piece of silk until the steel was perfectly dry. Tin foil was next pressed down so as to cover completely the steel surfaces, and wooden casings were tied on over this. This method proved perfectly efficacious; but if oil be left on the steel, rust will inevitably form.

(17.) The instruments and baggage were shipped at Bombay on the 26th April on board the S. S. Deccan. On the 28th I sailed, and on the 5th of May I landed at Aden.

Mr. Keelan had secured a store room there which was well adapted for the observations. It was single storied, solidly built with a "paka" floor, and but few windows. It was near steamer point and adjoined the Prince of Wales Hotel.* A transit pillar had been built in a convenient position between this room and the sea. The pendulums were not swung on isolated pillars at Aden. At Aden Mr. Keelan executed a small piece of triangulation to connect the pendulum room with the light ship, the latitude and longitude of which were known. He also took some circum-meridian observations of stars as a further check on the latitude.

(18.) Distilled water is now plentiful in Aden, and the Garrison is not so dependent on the tank water as was formerly the case. During our stay the Brigade Major kindly permitted the establishment of the party to be supplied with water at the Government rate of allowance.

The weather was of rather an unusual type at Aden for May. High winds made the atmosphere pleasantly cool, and there were two or three apologies for showers of rain. The nights were rather cloudy, but otherwise every thing went smoothly, and we left Aden on the 26th of May in the S.S. Nubia.

(19.) We arrived at Suez on the 1st of June. I tried there to hire a steam launch in which to take every thing round to Ismaïlia by the Canal, but I could not obtain one. I therefore landed the instruments and baggage at Suez. Some delay and difficulties occurred in passing the things through the Custom House, but eventually owing to the exertions of our Consul, Mr. West, we obtained the necessary permit. I then hired and loaded a Goods Van, and on the 4th we reached Ismaïlia.

(20.) The observations at Ismaïlia were taken in a room on the ground floor of the Hotel Pagnon, a large double storied building. The pendulums were not swung on isolated pillars, but the floor of the room was laid with encaustic tiles and was very solid. The clock hung from a steel pin firmly driven into the wall; and this method of suspension suited it very well.

For the transit instrument a pillar of stone-work was sunk one and a half feet in the sand in the garden of the Hotel. When the masonry was dry, there were placed on the pillar the 3 large triangular stones which were formerly used for the stand of one of the astronomical circles, and which I had brought with me for this purpose. On the top of these the transit instrument was set up. This extemporised pillar answered its purpose very well.

(21.) The French officers, in charge of the Canal, at Ismaïlia were particularly civil in their offers of assistance. They presented me with plans of the Canal and of the town from which the latitude and longitude of the hotel could be satisfactorily laid off. They also gave me the height of the floor of the pendulum room above the sea level at Suez.

(22.) Ismaïlia is a most remarkable place, and exemplifies very strongly the capacities of the French for producing neatness and beauty under difficulties. The town is situated on the shores of Lake Timsah; a lake about 3 miles long by 2½ wide, which was perfectly dry before the water was let into the Canal, but which now forms an admirable anchorage for passing ships. Ismaïlia is about 1½ miles distant from the Canal, and except for the waters of the lake, the town is surrounded on all sides by the most utter desert of sand: sand which is constantly shifting, and which is only prevented from invading the town by successive lines of reed

* Full detailed descriptions of the positions of the buildings in which the pendulums were swung at Coluba, at Aden, and at Ismailia, will be found in the pendulum observation books.

fencing. Yet in the midst of this one finds good roads with avenues of trees: a town of solidly built houses, many of them double storied, and several of them with considerable architectural pretensions. There is a public garden with a pretty kiosk and fountain in the centre, surrounded by beds kept in the neatest order, full of handsome shrubs, and bright with geraniums, zinias and oleanders. Most of the private houses have bits of gardens, and that of M. Lesseps is a most perfect little wilderness. A plentiful supply of water is obtained from the sweet water Canal which surrounds the town, but water alone will not make the desert sand fertile, and the soil of the gardens is black earth which underlies the sand and which has been dredged out of the canal. At one end of the town is a large unoccupied palace built by the Viceroy, and adjoining it are the water-works whence fresh water is pumped to Port Said.

Although the European population might be counted by tens, and is composed almost entirely of Canal officers; yet there are one or two cafés chantant in the town and a bathing establishment by the Lake. The lake is most admirably adapted for bathing. The bottom is all sand, and there is plenty of water a short distance from the shore. Owing to the large amount of evaporation the water is intensely salt, and in consequence wonderfully buoyant.

The weather was remarkably fine during our stay at Ismaïlia. In the middle of the day, the heat out of doors from the glare and radiation was considerable; but within doors it was cool enough; and though one or two of the days were somewhat sultry, yet the heat bore no comparison to that of upper India in June. When we first arrived the atmosphere was wonderfully clear, and the hills near Suez, which were some 60 miles distant did not look more than 15 miles away. Later on we had high winds which filled the air with sand and made it very murky. The nights were of the most glorious description. Even at Mussoorie after the monsoon I have never seen the heavens more brilliant than they were at Ismaïlia, and the milky-way shone like patches of sun-lit clouds.

(23.) On the 25th of June we left Ismaïlia. I took 7 natives of the establishment, on with me to Alexandria to assist in shipping the instruments there. The remainder I sent back to Suez. I had taken the precaution to obtain through Mr. Vivian, Acting Consul General at Alexandria, an export order which enabled me to pass the instruments and baggage through the Custom House there without delay, and on the 26th every thing was shipped on board the S.S. Candia. I then sent back the rest of the natives to Suez, where I had arranged for their passages back to Bombay, with Mr. Sullivan, the Peninsular and Oriental Company's Agent.

(24.) On the 3rd of July we left Alexandria for Southampton. Right glad was I to bid farewell to Egypt. The Egyptians are the most aggravating people to deal with that I ever encountered. At Suez I was obliged to engage a dragoman as interpreter, one Ali, whom I have no reason to suppose was much below the average of his class. I knew he was not to be trusted, and so when I had got a pass from the Custom House at Suez, I went up myself to the Station to arrange for a goods van. I paid for it, and it was to be sent down to the Custom House that evening. When I went over next morning it had not arrived so I sent Ali up to the station for it. He came back with the intelligence "Engine driver not bring waggon les he get 4 shillings." Time was important so I paid. The waggon arrived soon after but with the door locked. Ali was sent for the key, and came back to say "Man not come and open door les he get 6d." When we had nearly finished loading the waggon, an official came and talked with great volubility to Ali, who said he was objecting to the amount we were putting into the waggon. Fortunately he was a little late, the last box was put in and I locked the door and pocketed the key. The same sort of thing went on when we were starting by the train. Surrounded by loafers and beggars with every sort of hideous disease I was stowing the thermometers and barometers safely in the carriage, when Ali came up with some half dozen attendants to say "This man he not label luggage les he get six pence." "This "man he weigh luggage and make him 200 under, he want shilling." "This man . . . . " I thought, fortunately, of the thermometers and said. "Here, take this half crown and settle." But at Ismaïlia when I had got all the instruments safely lodged, I was able to devote a little more attention to Ali, and when on my objecting to the price of some stone he had brought for the transit pillar, he told me "him all come from France by canal boat" I explained to him pretty fully that I could not be called a fool so openly any longer. Ali improved very much after this, though he never could get over his habit of giving a ready answer to every question. But I think the only true thing I ever heard him say was "Every one in Egypt him like money. No do nothing without money." The Egyptians have one good trait. They can and do carry the most wonderful loads. At Ismaïlia we got the air pump and box weighing altogether 374 lbs. on to one man's back, and he managed to carry it in the teeth of a fresh breeze a distance of nearly a quarter of a mile.

(25.) On the 16th of July we landed at Southampton. I had written for a Custom House pass, and for a Furniture Van to meet the Steamer there. On the 17th the instruments were all packed in the Van, and were sent to the Kew Observatory where they arrived and were unpacked on the 18th instant.

(26.) Owing to General Sir E. Sabine's forethought, and kindness I found that the pendulum rooms had been fully prepared for my arrival. The invariable pendulums were

swung in the same place in which they had been swung by Mr. Loewy in 1865. The observations with these pendulums were finished on the 25th of August. Sir E. Sabine permitted Mr. G. Whipple, the Senior Assistant of the Observatory, to take transits for me during the time I was swinging the invariable pendulums. This work Mr. Whipple performed to my entire satisfaction. The transits were observed directly by the Shelton clock, the beats of which were plainly audible in the transit room through a tube carried up from the clock. The clock face could be seen from the transit room reflected in a mirror.

(27.) I did not leave Kew until the 13th of July 1874. The interval between August 1873 and this date was spent in taking a complete set of observations with the Russian reversible pendulums for the determination of the length of the simple seconds pendulum at Kew; in reconstructing and swinging the convertible pendulum used by Captain Kater in 1817; and in determining certain factors connected with the invariable pendulums.

(28.) In the original programme drawn up by you for the completion of the pendulum operations it was intended that the invariable pendulums should be swung at Greenwich as well as at Kew. From the known length of the seconds pendulum at Greenwich, as determined by General Sir E. Sabine, a value of the length of the seconds pendulum at the Indian Stations of observations would have been then obtainable. Owing, however, chiefly to the extensive preparations which were being made at Greenwich for the Transit of Venus parties, no space was available in the Observatory for the pendulum experiments, and the Astronomer Royal proposed that the pendulums should be swung not at the point in the Observatory at which Sir E. Sabine has swung his pendulum, but in a building to be erected temporarily for the purpose in the park about 300 yards from the Observatory and pulled down on the completion of the swings. Application was therefore made to the British Government by the India Office for a grant of £200, for this building.

The grant was eventually sanctioned, but in the mean time a change had been made in the programme of operations.

In August Sir E. Sabine suggested that I should undertake a series of observations with Captain Kater's convertible pendulum. You sanctioned this arrangement which by forming Kew into a base Station makes the Indian experiments independent of Greenwich.

(29.) Throughout my stay at Kew, Sir E. Sabine, who took great interest in my work, was constant in his enquiries as to my progress, and in his kind offers of assistance. He placed at my disposal the occasional services of Sergeants Moore and Chadwick of the Royal Artillery whom he employed as writers. These men were both neat and accurate in their work, and were very useful in making out duplicates of the records of my observations and in assisting in the computations. I am also much indebted to Mr. S. Jeffery, the Superintendent of the Kew Observatory for the assistance he afforded me, and my best thanks are due to Messrs. G. Whipple and T. Baker for the numberless little services they so freely rendered me.

(30.) Mr. H. E. T. Keelan, Surveyor 3rd grade joined the party in December 1873. Mr. Keelan was about to take sick leave to Europe, when you offered him this opportunity of accompanying the party to England on duty. Mr. Keelan's services have proved most valuable to me, and although he has occasionally suffered from severe headaches, yet on the whole his health has been better than might have been anticipated. He possesses all the qualifications which an assistant should have and is moreover clever at designing. He made very satisfactory designs and drawings for several things which I required at Kew for Kater's pendulum, and I am indebted to him for many little suggestions in other ways. At Kaliána he was instructed in the methods, of observing coincidences, and of clock comparisons. Throughout the operations he observed some of the intermediate coincidences of the invariable pendulums and took some of the clock comparisons. Towards the close of the work at Kew he practised himself in taking star observations for time with the Transit Instrument; and his average probable error for the mean time of transit of a star for the last four nights of his observations was but $\pm$ 0·03 sec. The results of the observations show him to be a very competent observer; and more especially is this the case with the clock comparisons which he took at Kew for the determination of the rate of the Shelton clock from telegraph signals transmitted from the Greenwich Observatory clock to the Richmond Post office. At Aden he executed a triangulation for the determination of the Latitude of the pendulum room, and he took there some circum-meridian observations to stars for the same purpose. Mr. Keelan's work has been more than satisfactory in every respect and I cannot commend him too highly.

(31.) Before I left Kew I handed over to Mr. Jeffery, the Superintendent of the Observatory, who had been deputed by the Royal Society to take charge of them, the invariable pendulums and the whole of the pendulum apparatus. A great part of this apparatus had been constructed at the expense of the Indian Government: but, acting on your suggestion, these portions, including the vacuum apparatus, thermometers and syphon gauges, were presented by the Indian Government to the Royal Society.

After leaving Kew I spent a week in London where I handed over to the Director General of Stores the boxes containing the records of my observations, and the office books and papers for despatch to this country.

The Russian pendulums were shipped under Mr. Keelan's superintendence and were

despatched to St. Petersburg, in the same condition in which I had last used them at Kew. I have since heard from M. O. de Struve, to whom they were consigned, that they appeared to have reached Russia in good order. In accordance with a request I made, he has deputed a skilled officer to take a series of observations with the pendulums in the condition in which they arrived, and I trust that the results in India and at Kew will thus become connected with those made in Russia. Such of the few instruments as remained, I transferred to the India Store Department for repairs before being returned to this country. On the 20th of July Mr. Keelan availed himself of the furlough, and I availed myself of the privilege leave which had been granted to us.

I embarked for Bombay by the mail which left Southampton on the 17th of September, and I reached Dehra on the 20th of October.

Extract from the Narrative Report—dated 20th November 1874—of J. B. N. HENNESSEY, Esq., Deputy Superintendent 1st Grade, G. T. Survey, In charge Computing Office.

Calculating Branch.

(2.) The following changes have occurred during the year under review.

Computing Branch. Lieutenant St. G. C. Gore who was posted to this office at the close of the preceding year, to be instructed in the calculations of the Department, having gone through the usual course, and having afterwards done duty in the office, was, on the 1st August, transferred to the Kumaun and Garhwál Party. Mr. W. Todd, Surveyor 2nd Grade, joined on the 1st January 1874 from the same Party and on the same date Mr. J. W. Macdougall was transferred to that Party. Mr. McCarthy, entered as a computer on the 11th June, and having subsequently passed the usual examination required of candidates for admission to the Junior Department, was appointed an Assistant Surveyor, 4th Grade, on the 11th August. On the 1st February he also was transferred to the Kumaun and Garhwál Party.

Drawing Branch. Mr. Atkinson was absent on two months leave from the 25th August, during which time Mr. H. F. W. Todd officiated for him.

Summary of work performed by the Computing Branch.

(3.) A large amount of the work performed by the Computing Branch—being, as it is, closely connected with the other Branches of the office—is of necessity of such a miscellaneous character that it would be impossible to reduce it within the form of a summary. Such as can be so reduced, is detailed below; but in order to enable you to form a general idea of the progress that has been made I will first briefly capitulate some of the more important subjects that have occupied the time of the office. The printing of Vols. III and IV of the *Account of the Operations &c.* which contain the numerical data connected with the Principal Triangulation of the N.W. Quadrilateral, were, as stated in my last report, then practically in a complete state. They have been put aside in accordance with your directions pending the completion of Vol. II on which you are now engaged, without which they would be to some extent unintelligible. Of this volume about 250 pages have already been passed through the press. No similar reason has existed for retarding the publication of the Principal and Secondary work of the same Quadrilateral (in the form prescribed by yourself) for the use of local officials and others, engaged on survey or other work for which geographical data are requisite. The Quadrilateral is divided into eight series of each of which a synopsis has been or is being prepared, containing the elements of all the principal and secondary points connected with it and accompanied by charts of the triangulation. Of these synopses, Vol. I, or that of the Great Indus Series has been published; Vol. II, or that of the section of the Great Arc between lats. 24° and 30° is now almost ready for the binder; Vol. III, or that of the Karáchí Longitudinal Series, is very nearly equally advanced; those of the Gurhágarh and Jogí-Tíla Meridional Series are complete with the exception of charts, and the Rahun Meridional Series is nearly out of the printer's hands but also needs charts. The two remaining series *i. e.*, the Sutlej and N.W. Himalaya are in a somewhat backward state, only the synopsis of the principal points having been as yet printed; the secondary data of the former are ready for the press, and considerable progress has been made in preparing the data of the latter. The reduction of the secondary triangulation into accordance with the principal triangulation, prior to the preparation of the synopses, necessitated by the final reduction of the N.W. Quadrilateral, has of course entailed much labour on the Computing Branch, as also has the superintendence through the press of the publication of the result. In addition to this considerable progress has been made with the reduction of the next Quadrilateral, *i. e.* the S.E., for which triangles, latitudes, longitudes and azimuths have been computed and the absolute terms of the equations found; also good progress has been made in determining the coefficients of the unknown quantities involved. These calcula-

Calculating Branch.—(Continued).

tions have had to be set aside for the present, as several of the computers are engaged in the reduction of the observations made by Captain Trotter while attached to the Yarkund Mission, in accordance with your wish that every facility should be afforded to that officer, to enable him to complete his report and compile the maps connected with his work as soon as possible. Besides this, Captain Heaviside also has the services of a computer placed at his disposal.

(4.) The details of the ordinary calculations are as follows :—

Angle Books indexed	64 vols.
Deduced Angles examined	32 angles
Abstracts of Angles compared	166 „
Zero and general means computed	166 „

Computations in Duplicate.

Principal Triangulation.	Weights computed	192
	Spherical Excesses computed	221
	Simple Quadrilaterals reduced	14
	Simple Polygons „	29
	Compound Figures „	14
	Lats., Longs., and Azimuths computed (single deductions)	92
Secondary Triangulation.	Traverses computed	6
	Ray Traces „	8
	Triangles „	1505
	Do. adjusted	632
	Lats., Longs., and Azimuths computed ..	2258
Explorations.	Latitudes by Circum-meridian observations	121 deductions
	Heights by Boiling Point	88 points
	Longitudes by Z. D.	about 30 deductions

(5.) The work performed in connection with the Typographic and Photozincographic presses is given under two heads.

For Typographic Office.

Synopses of the Operations, &c.	Compiled or otherwise prepared.
Letter press	26 pages
Principal Triangles	13 „
Principal Lats., Longs., Azimuths and Heights	29 „
Secondary Triangles	136 „
Azimuth Tables	64 „
Co-ordinates of Secondary Points	129 „
„ Peaks (N.W. Frontier)	6 „
Total	403

For vols. III and IV of the operations &c.	
Letter press	45 pages
For other vols. of the operations &c. Lists, Descriptions and observed angles of	
Revised Calcutta Longitudinal Series	104
Great Arc Series, lat. 18° to 24°	66
Jabalpur Meridional Series	10
Total	180

The auxiliary reductions of the figures of the N.W. Quadrilateral have also been compiled for inclusion in Vol. II.

For Photozincographic Office.

Data compiled for projection of Assam Series Chart 55-60 ..	1 sheet
Numerical and other Charts.	Compared or Examined
Engraved proof of N.W. Quadrilateral Reduction	1 sheet
S.E. Quadrilateral Chart	1 „
Assam Series Chart 1855-60	1 „
Jodhpúr Series Chart 1872-73	1 „
Final Charts Great Indus Series	4 „
Total	8

Calculating Branch.—(Continued).

Instrumental Work.

(6.) Observations for time were taken on 10 occasions during the year for the purpose of showing mean time and rating chronometers. Meteorological observations were made in the Dehra Observatory on every day throughout the year, and the daily results were reduced and communicated month by month, as usual, to the Reporter on Meteorology, N. W. Provinces. A table of monthly means is appended to this report. The difference of level between the upper mark of the Dehra Dome Observatory and the B. M. in the wall of the G. T. S. Office was determined by Spirit Leveling; and the large Anemometer, which had for some time been awaiting a suitable place on which to erect it, was put up over the room which surmounts the portico of the office and the clock work with registering barrel placed beneath within the same room.

Pendulum Observations.

(7.) I noticed in my last report that on Captain W. J. Heaviside's appointment to the charge of the Pendulum operations, I was able to afford him assistance in certain matters connected with his work: having more calculations than his own office could perform, he continued to require the aid of the computing office for some time during the year under report. The work executed for him was the computation of the rates of the Russian and English sidereal clocks in connection with his observations at Kaliána; the reduction of 81 sets of observations with the Russian Pendulums at Kaliána and the preparation of an abstract of the same; the bringing up of tables for the reduction of the measurement of length for both pendulums; the recomputation of the Russian clock rates for the Kaliána observations; the copying of 72 sets of observations at Kaliána with the Russian Pendulum No. 2; the computation of the observations with the Russian Pendulum at More; the reduction of clock rates for the observations at Dehra, and the reduction of the observations with the Russian Pendulum at the same place; the reduction of the observations at Kaliána made on the occasion of the fourth visit to that station: the bringing up of the abstract of the results; the recomputation of the factor of expansion for the Royal Society's Pendulums and the bringing up of the temperature corrections, &c.

Protection of Stations.

(8.) The preservation of the Principal Stations of this Survey is of course a matter of the utmost importance and entails a good deal of correspondence on this office. Replies to 233 letters on this subject were drafted by Mr. C. Wood under your direction, and 12 original, duplicate and supplementary lists including 76 stations were issued to district officers. Owing to the modern alterations in the boundaries of districts it is often a matter of some difficulty to ascertain what stations are situated in each district and to obtain a complete return from the district officials. Steady progress is however being made, and I am glad to state that since I last reported 53 more districts including 550 stations have been settled, making in all 291 districts of which the lists are now complete.

The check lists now include about 2,450 principal stations. A statement was also prepared shewing what district officials had failed to send in Annual Reports of the condition of the stations in their districts, and reminders have been sent to them, the result of which has been in most cases satisfactory.

Miscellaneous.

(9.) A new form for the computation of trigonometrical heights has been devised by which the labour of calculation is considerably reduced and in connection with this form a new table has been added to the Auxiliary Tables. Forms for official and departmental use were supplied to 55 officers, and 446 parcels containing maps and charts were booked and despatched. Twenty-nine officers have been supplied with data, that furnished to Captain Bailey of the Forest Department was more over all reduced to the same terms. Abstracts of observed angles and approximate azimuths were prepared for all the stations of the Bilaspur Meridional Series, Southern Section, visited during the season of 1872-73. Lists of pargana, patti, and village names in Kumaun and Garhwál were prepared for submission to the settlement officers for correction of orthography, and 6 candidates for the junior department were examined.

Typographic Branch.

(10.) The work performed by the Printing Office for the past 5 years is concisely stated in the following table.

	1869-70	1870-71	1871-72	1872-73	1873-74
Pages composed,	693	819	1,143	1,420	1,220
Do. printed,	106,231	234,828	241,348	273,157	388,420

Typographic Branch.—(Continued).

The total pages composed last year may be subdivided thus,

For volumes of the G. T. Survey	870
For charts, memos., &c.	224
For Annual Report	126
Total	1,220

Drawing Branch.

(11.) The work executed in the Drawing Office is exhibited in the table which follows this report.

Photozincographic Branch.

(12.) The work performed by this office is shown in the following tabular statement under the heads of Maps, Charts, Diagrams and Forms.

Maps.

Subject	When published	No. of parts	No. of copies printed
Prints of maps published in former years	..	12	750
Kattywar, sheet No. 29	May 1873	1	220
Do. No. 30	„ „	1	69
Turkestan Map, sheet No. 2 (2nd edition)	„ „	1	464
Do. No. 3 „	„ „	1	290
Do. No. 4 „	June „	1	557
Do. No. 1 „ addendum .	„ „	1	253
Index to Mussoorie & Landour Survey	„ „	1	8
Do. to Triangulation, S. E. Quadrilateral ..	August „	1	34
Guzerat, sheet No. 11	„ „	1	123
Kashmir Map (for Major Bates's Gazetteer)	September „	1	559
Index to Guzerat Survey..	„ „	1	522
Do. to Kattywar	October „	1	681
Forest Map	„ „	3	405
Kattywar, sheet No. 13 (N. W. Section)	„ „	1	61
Index to Kumaun & Garhwál Survey	November „	1	406
„ Main Lines of levels (reduced scale)	„ „	1	412
Trans-Frontier Map No. 9	„ „	1	119
Kattywar, sheet No. 13 (S. E. Section)	„ „	1	55
Turkestan Map, sheet No. 1 (2nd edition *reprint*)	„ „	1	320
Do. No. 3 („ „)	December „	1	333
Kattywar, sheet No. 23	„ „	1	132
Do. No. 24	„ „	1	132
Do. No. 25	„ „	1	25
Do. No. 13 (S. W. Section)	„ „	1	55
Guzerat, sheet No. 13	„ „	1	105
Doonga Gulli Forest Map (reduced)	„ „	1	111
Trans-Frontier Map No. 8	January 1874	1	115
Forest Map (Hazara district) W. Section	„ „	1	53
Do. („) Central Section .. .	„ „	1	54
Kattywar, sheet No. 10	„ „	1	129
Do. No. 20	„ „	1	105
Do. No. 21	„ „	1	129
Do. No. 11	„ „	1	161
Do. No. 22	„ „	1	151
Guzerat, sheet No. 12	„ „	1	105
Kumaun and Garhwál, sheet No. 25, contoured	„ „	1	105
Do. „ No. 26 „	„ „	1	105
Forest Map (Hazara district) E. Section	„ „	1	10
Kumaun & Garhwál, sheet No. 34, contoured	February „	1	105
Do. No. 33 „	„ „	1	106
Forest Map (Khanpur Range of Rakhs &c.,) E. Section ..	„ „	1	161
Do. („) Central Section ..	„ „	1	6

Photozincographic Branch.—(Continued).

Maps.—(Continued).

Subject	When published	No. of parts	No. of copies printed
Kattywar, sheet No. 13 (N.E. Section)	February 1874	1	55
Index to Preliminary Charts (N.W. Quadrilateral)	March „	1	35
Kumaun and Garhwál, sheet No. 34, skeleton	April „	1	105
Guzerat, sheet No. 10	„ „	1	106
Kumaun & Garhwál, sheet No. 32 skeleton	„ „	1	105
	Totals ..	61	9,207

Besides the foregoing, Blue prints 53 in number were issued.

Charts.

Amua Series No. 1	May 1873	1	66
Do. No. 2	„ „	1	68
Assam Longl. Series, season 1855-60 Numerical	December „	1	65
Brahmaputra Series, season 1872-73 „	„ „	1	65
Gora Series, No. 1 .. „	„ „	1	65
Jodhpur Series, season 1872-73 „	January 1874	1	65
Biláspur Series „ „ (N. Section) Numerical ..	February „	1	65
Great Indus Series, Chart No. 1, Final		1	377
Kadappa and Karnúl Minor Triangulation (1871-73) Numerical	March „	1	65
Great Indus Series, Chart No. 2. }	„ „	1	359
Do. No. 3. } Final	April „	1	375
Do. No. 4. }	„ „	1	392
	Totals ..	12	2,027

Diagrams.

Subject	When published	No. of copies printed
Plates to illustrate Vols. III and IV and other diagrams,	May 1873	710
	June „	220
	July „	160
	August „	160
	October „	320
	November „	807
	March 1874	1080
	April „	100
	Total ..	3,557
Professional and Office Forms, ...	1873-74.	28,125

1,400 Maps and 2,702 Charts were issued during the year. The forms are always expended as fast as printed. Contrasting the work performed since 1870-71 we have

Year	Maps	Charts	Diagrams	Forms
1870-71	6,465	839	13,205	10,482
1871-72	10,131	1,375	4,937	13,655
1872-73	6,910	2,206	12,055	12,549
1873-74	9,207	2,027	3,557	28,125

Photozincographic Branch.—(Continued).

An Abstract of the work executed during the past five years stands as follows.

Subject	Number of Prints				
	1869-70	1870-71	1871-72	1872-73	1873-74
Maps, Charts and Diagrams,	12,315	20,509	16,443	21,171	14,791
Forms, ...	13,571	10,482	13,655	12,549	28,125

These tables speak for themselves as to the value of this branch of the office when judged of only by the out-turn of work; but the nature of the work is in many instances such that the convenience of having a small establishment of this kind at hand to execute it is inestimable. The accuracy of the data on the Preliminary Charts and the Charts of Levels alone, which is of the utmost importance, could not be so well assured if this branch were not in direct connection with the drawing and computing branches, without entailing delay and correspondence which would seriously impede the current work not only of the office but frequently of the department itself.

(13.) In conclusion, Mr. W. H. Cole, M.A. has continued to render valuable service in discharging the varied duties that are required of him.

Mr. Wood is as efficient as ever. Mr. Peychers works steadily and to good purpose. Baboo Gunga Pershad continues to be an excellent assistant. Baboo Cally Mohun Ghose has done good service. Baboos Kally Coomar Chatterjee, Gopal Chunder Surear and Tarapodo Mookerjee are deserving of commendation, and of the new hands Baboos Sham Nath and Shoshee Bhooshan Shome have mostly afforded satisfaction.

Mr. W. Todd has worked with his well known accuracy, care and zeal.

Mr. Ollenbach and Mr. Dyson have both done well.

Mr. O'Connor's zeal and professional ability are commendable.

Mr. Atkinson has conducted his duties as Chief Draftsman with success; his assistants have given satisfaction.

MONTHLY Meteorological results taken from the Register kept at the Office of the Superintendent G. T. Survey of India, Dehra Dún.

YEAR & MONTH.	BAROMETER. At 9 h. m. 30 A.M.			BAROMETER. At 3 h. m. 30 P.M.			HYGROMETER. At 9 h. m. 30 A.M.		HYGROMETER. At 3 h. m. 30 P.M.		THERMOMETER. Dry Bulb.				THERMOMETER. Wet Bulb.			RAIN.		WIND.	CLOUD. At 9 h. m. 30 A.M.	CLOUD. At 3 h. m. 30 P.M.
	Highest.	Lowest.	Monthly mean.	Highest.	Lowest.	Monthly mean.	Monthly mean Temperature of Dew point.	Monthly mean Humidity.	Monthly mean Temperature of Dew point.	Monthly mean Humidity.	Max.: in Sun's rays.	Min.: on grass.	Max.: in air.	Min.: in air.	Monthly mean in air.	Max.: wet.	Min.: wet.	Monthly mean wet.	No. of days it fell.	Fall in inches.	Average direction.		
1873.	in.	in.	in.	in.	in.	in.	°		°		°	°	°	°	°	°	°	°					
January	27·854	27·573	27·739	27·779	27·535	27·660	44·7	·698	43·3	·429	83·1	31·0	78·4	35·4	56·7	61·3	32·0	46·8	3	1·08	N.	3	4
February	·912	·514	·740	·825	·434	·653	47·7	·611	45·6	·376	92·8	39·3	83·1	43·0	62·8	65·0	35·1	51·2	3	0·34	S.	2	2
March	·767	·541	·673	·666	·437	·576	49·0	·519	45·9	·324	103·1	42·8	91·2	45·8	67·9	67·5	38·2	53·9	4	1·21	W.	3	4
April	·705	·491	·571	·588	·381	·470	46·5	·284	45·1	·203	109·6	54·6	97·9	57·2	79·1	71·9	41·6	58·3	0	0·00	S. & W.	0	1
May	·712	·338	·555	·643	·253	·470	57·8	·445	56·6	·362	117·3	57·9	103·1	60·8	79·5	79·1	51·5	63·2	8	2·01	E.	4	4
June	·436	·242	·339	·353	·134	·246	65·7	·461	63·1	·330	116·2	64·9	105·6	68·6	88·2	81·0	55·8	64·1	3	0·60	W.	1	2
July	·462	·259	·349	·346	·202	·281	75·2	·819	75·9	·768	113·8	68·8	102·0	71·0	81·5	82·0	64·8	74·0	26	28·45	S.W.	7	8
August	·556	·408	·478	·476	·331	·396	75·1	·837	75·8	·801	104·1	69·4	90·0	70·8	79·7	81·9	64·0	73·4	20	21·43	N.	6	7
September	·664	·414	·525	·568	·341	·449	71·6	·800	72·6	·753	102·1	62·8	90·5	65·1	77·1	82·0	57·4	69·8	14	10·52	S.	4	5
October	·800	·650	·706	·680	·557	·618	57·0	·619	57·6	·482	99·4	45·2	85·2	49·0	69·2	79·4	40·3	58·3	1	0·09	W.	0	0
November	·931	·743	·849	·824	·643	·762	49·2	·594	49·0	·432	93·0	41·8	78·8	46·4	62·9	67·2	38·6	50·7	0	0·00	E.	1	2
December	·931	·670	·828	·846	·612	·743	46·0	·700	46·6	·493	84·5	36·1	73·0	41·0	56·6	67·2	32·4	47·9	4	0·91	S.	2	3

NOTE.—The height of the Barometer Cistern above Mean Sea Level at Karáchí is 2232·41 feet.

Annual Return of work executed in the Drawing Branch of the Office of Superintendent G. T. Survey of India, from 1st May 1873 to 30th April 1874.

Description of Work.	Number of sheets or diagrams. Finished	In hand	Scale 1 inch =	Remarks.
Compilation.			Miles.	
Sheets Nos. 2, 3 and 4, Turkestan Map (2nd edition)	4		32	For Photozincography.
Sheet No. 4, Turkestan Map (3rd edition)		1	32	ditto.
Addendum to sheet No. 1, Turkestan Map (2nd edition) ...	1		32	ditto.
Trans-Frontier Maps Nos. 8 and 9	2		16 & 8	ditto.
„ Map (containing Rakas Tal and Mánsorawar Lake)	1		4	ditto. Sheet No. 9 for reduction to ½ scale.
Map of Kashmir to illustrate Major Bates' Gazetteer of Kashmir	1		16	ditto.
Map of Kumaun and Garhwál to illustrate Mr. E.T. Atkinson's Gazetteer of Kumaun and Garhwál		1	4	ditto. Reduction to ½ scale.
Sheet No. 6 of Spirit-Levelled Heights		1	2	ditto.
do. „ 13 do. do.		1	2	ditto.
do. „ 25 do. do.		1	2	ditto.
do. „ 26 do. do.	1		2	ditto.
Index Map to Mussooree and Landour Survey sheets shewing the position of Boundary Pillars	1		2	ditto.
Preliminary Numerical Charts.				
Assam Longitudinal Series, Seasons 1855-60	1		4	ditto.
Jodhpur Meridional Series, „ 1872-73	1		4	ditto.
Kadappa and Karnúl Minor Series (Great Arc Revision), Seasons 1871-73	1		4	ditto.
Mangalore Meridional and Madras Longitudinal Series, Seasons 1871-73	1		4	ditto.
Biláspur Meridional Series (Southern Section) Season 1872-73	1		4	ditto.
Final Charts.				
Great Indus Series	4		4	ditto. Reduction to ½ scale
Great Arc „		2	4	ditto. ditto.
Gurhágarh „		2	4	ditto. ditto.
Jogi-Tila „		1	4	ditto. ditto.
Karáchí „		2	4	ditto. ditto.
Rahún „		2	4	ditto. ditto.
Sutlej „		1	4	ditto. ditto.
Rough Chart of the South-East Quadrilateral	1		20	ditto.
2 Charts of the chains of triangles west of the meridian of Calcutta	2			ditto. ditto.
4 Copies of Star Charts	4			ditto.
Miscellaneous.				
Prepared 28 Forms professional and office on Transfer and Drawing paper				For Zincography and Photozincography.
Examined proofs of 81 maps and charts				
Colored 6,862 copies of different maps				
Prepared Diagrams and Descriptions of Bench-Marks for sheet No. 26 of Spirit-Levelled Heights				
Reduced and combined several sheets of levels				
do. do. several routes				
do. several Russian and other maps for incorporation in Turkestan and Trans-Frontier Maps				
Prepared several tracings for use of Officers				
Examined and reported on 18 fair maps of the Kumaun and Garhwál, Kattywar and Guzerat parties and performed numerous other miscellaneous duties				

Particulars of the transit of Venus across the Sun, December 9, 1874, observed at Mary Villa, Mussoorie, on the Himalaya Mountains, by J. B. N. Hennessey, F.R.A.S., Deputy Superintendent 1st Grade, Great Trigonometrical Survey of India, in charge Computing Office.

PART I.

Naturally sharing in the great interest excited by the transit of Venus, I proposed that I should observe the event with the equatorial of the Royal Society which Captain J. Herschel, R.E. had temporarily placed at my disposal; and the project meeting with your approval and support, I was enabled to provide myself with 4 chronometers, a good alt-azimuth, a barometer, thermometer and other articles of equipment necessary for the undertaking. My especial object in view was to observe the transit from *a considerable height*, and this condition was easily secured through the circumstance, that in pursuance of my professional duties I was located only some 14 miles from Mussoorie on the Himalaya Mountains; no doubt a station on these mountains would be very liable to an envelope of mist and cloud at the time of year in question, but on the other hand, if really good weather prevailed, I should enjoy the exquisitely clear atmosphere such as I have never experienced save on the Himalayas: add to this, the journey as already stated was merely an ordinary ride, the necessary equipment for my purpose was at hand, and though failure would involve a waste of no inconsiderable preliminary labor, this latter I was willing to incur if need be. Arguing thus, I selected a station some 6½ thousand feet above the sea and proceeded to find my latitude, longitude and height, to observe for time and to rate my chronometers. My numerical results are given in Part II of this Appendix. The remarks now made are restricted chiefly to what I *saw* with the equatorial.

2. The telescope of the equatorial has a 5-inch object glass of about 5 feet focal length and is driven by an excellent clock; the eye-end of the telescope may be fitted at will with an eye-piece of 55, 85, 125, 200 or 300 power; or with a spectroscope mounting a single simple prism: the polar axis may be shifted for latitude. The equatorial was set up and adjusted in an observatory tent, of which the canvas top was removed during observation.

3. I found from actual trial, that the most suitable eye-piece for both ingress (sun's altitude 2° 24′ to 7° 29′) and egress (sun's altitude about 26°) was that of 125 power: accordingly this eye-piece alone was employed *at* the contacts. It was however impossible to adapt the same dark glasses for both the higher and lower altitudes, without sacrificing definition on one of the two occasions; accordingly I selected for ingress two glasses which combined gave a neutral or bluish field, and for egress I changed one of these for a deep red glass so that the field now presented a moderately deep red: the glasses were quite flat and lay against one another in intimate contact giving excellent definition. I may here add, that thanks to Manrakan, Artificer, G. T. Survey, the clock behaved with perfect regularity, nor was there the smallest instrumental disappointment throughout the work. As regards procedure during transit, Mr. W. H. Cole, M.A. with his usual kindness counted seconds audibly from the *journeyman* chronometer placed before him, while Baboo Cally Mohun Ghose took up a position by my side, pencil in hand, noting down such remarks as the phenomena, viewed through the equatorial, elicited from me. Nor, as we stood informed, were the events to be recorded few in number; at ingress, internal contact, the light between the cusps was suddenly to vary, the cusps were to meet; then should come the "pear drop", the "ligament"; what should be its length, what its breadth in terms of Venus' diameter, what its shape and which of the known descriptions would it resemble; when would it break? Primed on these points, we settled on a programme which included them all, and time after time we went through the necessary rehearsals for perfecting ourselves in our parts. So much for what we had to expect, and now for a few words on the weather.

4. I moved up to my mountain station on the afternoon of the 1st December; the day following I was busy fixing my station and adjusting instruments: up to this, the sky had been sufficiently clear; but from the 3rd there set in an alternation of weather, which without running into extremes, kept me in a state of miserable suspense, to say nothing of the additional watching and toil in observing for time. This state of affairs appeared drawing to a climax, when the 8th December arrived and the clouds looked blacker than ever, while the mist, which generally precedes snow-falls here, began to settle down on the internal and still more lofty ranges of hills; about 2 P.M. on this day there were a few drops of rain or sleet, so few that they might almost have been counted, and later on as the sun began to set, the heavy *cumuli* evolved themselves into strati, which spreading their even canopy over us, left something like decimal 0 of the sky visible; and this at 10 o'clock at night! At 4 next morning (9 December), when again reported on, the sky was without speck or cloud; the air was still, and so clear, so brilliantly clear, that even the most exacting of observers could not have desired more favorable circumstances for viewing the coming transit: in brief, I enjoyed most exquisitely clear weather during my observations, such as occurs not frequently even at Mussoorie. I now proceed to describe the phenomenon of the transit: in doing this I shall have occasion to speak of Venus as she appeared across the sun's limb, when a portion of her limb is seen against the sun

and the other remains against the sky; the former portion I shall call Venus' sun-limb or briefly V_n, the latter Venus' sky-limb or V_k. Again I shall require to mention a ring of light around V_k which I shall call L_k, the corresponding ring around V_n being understood by L_n. Another point is this; any one who has watched, say the sun's limb, especially at a low altitude and with high power, must be aware of the turmoil and ebullition which then appears very like as if the limb was being boiled: I shall denote this kind of turmoil by "boiling."

Ingress.

5. With the telescope well adjusted for focus, I watched for the first external contact; but to no purpose, for I did not see Venus' limb until after it had effected an indentation on the sun's limb; the latter boiled sensibly, yet by no means violently; it appeared jagged and as if with minute spikes projecting inwards, all of which were well defined in the bluish field. Watching V_n I found it also boiling slightly, but in a manner somewhat different to the sun's limb. The appearance was that of boiling vapour coming round, and overlapping V_n, from the face of Venus turned towards the sun; moreover this boiling was not restricted to the edge of V_n but extended 2' or 3' beyond, thus forming a kind of boiling annulus in which there were minute sparkling specks dancing and shifting about, appearing and disappearing; the edge V_n was *visible through* the boiling: so much for the portion of Venus seen against the *Sun*.

Ingress continued.

6. At 8½ minutes before the first internal contact, I happened to look closely into the spot where that part of Venus against the *sky* lay, and to my great surprise I found that this portion of her disc was easily visible, because it was edged by a narrow ring of light or L_k; at first I saw L_k only about 10° or 15° on either side of the point where the chord of Venus' track would cut V_k, or more definitely stated, this light-ring did not reach to the sun's limb; but within 50ˢ later I saw the light-ring distinctly round the whole sector of V_k, from edge to edge of the sun's limb. The ring-light was only moderately bright, like diffused light, and at first I estimated the annulus L_k at 3″ in width; it was probably brightest about the part where the chord above named cut V_k. At 6ᵐ before 1st internal contact, I estimated L_k at 4″ in breadth, at the same time my notes contain the remark "definition excellent". At 3ᵐ 24ˢ before 1st internal contact I remarked "light-ring quite distinct," and 1ᵐ 16ˢ later I stated "light-ring quite bright." Indeed the annulus L_k was so plain, that after recording the time of transit for the *dark* edge V_k, I even made a conjectural record as to the time when the bright edge L_k transited across the sun's limb; of course this estimate was based on *recollection* of the width of L_k and not on any *visible* fact, for as L_k came on the sun's disc the lesser light of the former merged into the latter. On the whole, I am of opinion that L_k was between 2″ and 4″ in width.

Ingress continued.

7. "And now for the pear drop, the ligament, &c.", I mentally exclaimed as I watched the following limb of Venus which had just transited. From what has been stated it will be seen, that as V_k passed onwards from the sun's limb it was immediately followed by the light-ring L_k, so that unless Venus *suddenly shot out backward across this ring of light*, it was plain there could be no "pear drop" and no "ligament." Fully expecting this retrogression, I still watched intently for the event, while Mr. Cole went on deliberately enumerating seconds, amid the complete silence enforced on all others around. But I watched for any such event in vain. Venus glided resolutely onwards, and the streak of *light* she was leaving behind grew wider and still wider, until at last when a belt of light representing 10 or 15 minutes of time lay between her and the sun's limb, I exclaimed, and I believe much to the disappointment of all concerned, "*there is no pear drop and no ligament.*" We watched Venus for some ½ hour after this and then turned to the spectroscope.

The spectroscope.

8. The substitution of spectroscope for eye-piece cannot be effected in this equatorial without a considerable amount of adjustment. When this had been performed, and we had taken a hasty breakfast, I first placed the slit across the *centre* of Venus' disc and found that it gave a black band all along the length of the bright solar spectrum; *i. e.* Venus' face turned towards us reflected no light. I next placed the slit tangential to Venus' disc; this gave a faint glimmer of narrow light *in place* of the black band; that is, *this glimmer was slightly brighter than the solar spectrum on which it appeared.* I looked intently for any Venus air-lines, but so far as the feeble dispersion of the prism would shew, the lines seen across the glimmering from Venus' edge were identical in all respects with the solar lines. I repeated these experiments as long as time permitted, and then with Manrakan's help reverted to the adjustments and the eye-end and eye-piece employed at ingress. As already stated, it was now necessary to substitute a dark red glass for one of those used at ingress.

Egress.

9. The field now was red and if anything slightly too dark to show faint lights; the definition was intensely sharp. Again, I watched with the utmost care as Venus approached her second internal contact, but *neither pear drop, ligament nor any other connection or shadow appeared between her edge and*

*that of the sun, until at last the two fairly touched.** Of course I again looked for the light-ring and certainly saw it 5^m after this contact when it was far less bright than at ingress: some time later I searched for the light-ring once more, but it was invisible; nor did I again see it, nor yet the disc of Venus against the sky. The remaining external contact needs no remark, excepting that it was seen with considerable exactness.

10. As already stated no *ligament* was visible to me at Mussoorie; it was however seen by yourself at Dehra, and by some other observers at certain of those few stations of observation whence some accounts of the phenomenon observed have been published in the local papers. How far these reports may combine to support one another and lead to the authoritative decisions which may be hereafter pronounced cannot of course now be predicted. For the present it appears to me probable, that height above sea level, inferiority of telescope, insensibility of the eye to faint lights and shadows and other causes, are all likely to conspire together towards producing a *ligament* at the internal contacts; but restricting myself to the first named of these causes, I venture on the following conclusions.

(1.) In view of the light-ring L_k and of the peculiar boiling annulus around V_n which may be called L_n, I have no doubt that L_n was in fact a continuation of the light-ring L_k, which latter beyond all question was plainly visible at ingress and less distinctly but still decidedly seen at egress; and under these circumstances it may be urged, that Venus is surrounded by an atmosphere or envelope, which at the time was made *visible* to the extent of 2″ to under 4″ in width.

(2.) As a matter of fact the pear drop or ligament was visible at a height of 2,200 feet, but at 6,500 feet of height the ligament was invisible; the influence generally of height of station appears undeniable; but the phenomenon still remains to be accounted for definitely. If however an effective envelope or atmosphere of x breadth around Venus be conceded, this atmosphere may be supposed to stop a certain amount of direct light from the sun, producing a slight shade around Venus corresponding to the breadth x; this shade would I conceive be quite invisible when its outer edge is backed by the sun's bright light; but could we contract the sun to a diameter equal to that of Venus plus twice x, and make Venus and the sun concentric, it appears likely that we should see a shaded annulus right round Venus between her limb and that of the sun; further that the annulus may appear darker at low than at higher altitudes, and may become invisible when the observer is raised above a sufficiency of the earth's atmosphere. Should these suggestions prove tenable, the ligament seen would break when the outer edge of the shade, corresponding to x, transited across the sun's limb.

(3.) Solar light shining through Venus' atmosphere (if any) produces no alteration in the lines of the solar spectrum so far as the dispersion of a single simple prism shows. Also Venus' face turned towards us, reflects no light during transit, subject to the same instrumental test.

PART II.

The instruments used were the following:—An Alt-azimuth by Troughton and Simms with an azimuth circle of 8 inches diameter read by 3 verniers, and a complete vertical circle also of 8 inches read by 2 verniers; the circles are divided to every 10′ of arc and the verniers afford readings to 10″, or by estimation to at least 5″: the instrument is well provided with spirit-levels surmounted by scales—the Alt-azimuth was used for fixing the station of observation and for determining time—

A mountain Barometer.

A good Thermometer.

Four Chronometers *viz*: Dent 2,047 used as a *journeyman* chronometer and packed in wool in a wooden box by itself; Barrauds 885, Dent 2,775 and Arnold and Dent 758, were the three *fixed* chronometers and were placed in the same case within a room, where the temperature had only a moderate diurnal range (probably under 8°); the case was well padded with wool and hemp and the chronometers were never moved between 4th and 10th December.

The Equatorial, has already been sufficiently described in Part I.

The point over which the Equatorial stood is called Venus Station; its co-ordinates are as follows, and were determined by angles from two known points fixed by the Great Trigonometrical Survey of India, *viz*., Camel's Back and Vincent's Hill Stations.

Venus Station.

Lat. N. 30° 27′ 36″·3; Long. east of Greenwich $\left\{\begin{array}{ccc} 78^\circ & 3' & 3''\cdot2 \\ \text{h.} & \text{m.} & \text{s.} \\ 5 & 12 & 12\cdot2 \end{array}\right\}$; Height above sea 6,765 feet.

* My notes state successively, that when the two limbs were apart $\frac{1}{4}$, $\frac{1}{6}$, $\frac{1}{8}$, $\frac{1}{12}$ and $\frac{1}{20}$ of Venus' diameter, there was no ligament or other connection.

Time was determined from the zenith distances of *α* Tauri (east) and *α* Aquilæ (west) when these stars were nearly on the prime vertical; as a rule 4 pairs of zenith distances were taken to each star, a pair consisting of one observation instrumental face east and another face west, taken in rapid succession; the chronometer time for each observation was obtained from transits over five horizontal wires; the resulting chronometer error by *each* pair was computed. The *journeyman* chronometer was compared with the three fixed chronometers before and after observation; and the errors and rates of the latter thus determined. Proceeding in this manner, and tabulating the *mean* of the results by the three fixed chronometers, it was determined

Astronomical date		Chronometer reading	Fast on local Mean time	Daily rate
		h. m. s.	m. s.	s.
December	4	6 47 18·5	1 31·2	
				+ 6·5
„	5	6 48 40·6	1 37·7	
				+ 7·5
„	6	6 37 19·1	1 45·1	
				+ 6·7
„	7	(Cloudy)		
„	8	6 42 12·1 18 56 17·4 23 17 19·4	1 58·6 2 2·2 2 3·5	
				+ 7·3
„	9	6 37 52·6	2 5·8	

(1)

On the day of transit, the *journeyman* was compared with the three fixed chronometers before and after ingress, and also before and after egress, and by employing the daily rate of + 7ˢ·3 and correcting the times of contact determined by the *journeyman* chronometer we obtain,

		Local Mean time
		d. h. m. s.
1874	1st internal contact occurred, December	8 19 29 19·3
	2nd „ „	23 17 42·9
	2nd external „	23 44 59·9

(2)

where the tenths of seconds come into existence through the arithmetical processes involved; the original times were recorded merely to the nearest second, and I have no doubt that the latter degree of rigour was much in excess of what the phenomena were susceptible, so that the procedure adopted for determining time appears amply rigorous.—Speaking roughly, 1″ of Venus' diameter took 26ˢ to transit, and supposing that I could see 0″·1 of the former (which I doubt) each contact should have lasted, visibly, for say 3ˢ. But as regards the estimates of accuracy I actually made *immediately after* the events, I find it recorded that I thought my times might be true within the following limits

Time of 1st internal contact	± 3ˢ to 4ˢ	
„ 2nd „ „	± 2ˢ	(3)
„ 2nd external „	± 1ˢ	

I am now however of opinion that these estimates (3) should be *increased* by one half.

From what has preceded, the Greenwich mean times of contact are

	h. m. s.	
1st internal contact	14 17 7·1	
2nd „ „	18 5 30·7	(4)
2nd external „	18 32 47·7	

there is however an incongruity in (4), for in this reduction the Longitude of Venus Station is taken east of Greenwich by $5^h\ 12^m\ 12^s·2$ = H, the origin for Indian longitude being adopted at $5^h\ 20^m\ 57^s·3$ E., for Madras Observatory; in reality however H refers, not to the *local meridian* necessarily adopted in (2), but to a computed meridian deduced from a concluded meridian of origin adopted for the principal triangulation of the Great Trigonometrical Survey at Kaliánpúr, whereas the times (2) refer to the *local meridian* as already stated. Denoting the value of H corresponding to the local meridian by H_1 we may find (nearly) $H_1 - H = h^s$ thus. Let A_o denote the azimuth of a terrestrial point P as determined by observations to a circumpolar star about its elongation and A_c the corresponding value as brought up by the triangulation from the concluded meridian of origin; also let $A_o - A_c = a''$ and let λ stand for the latitude of P_1 then it can be seen that as a correction to (4)

$$h^s = -\frac{a''}{15}\ \mathrm{cosec}\ \lambda$$

now a'' is not known at Venus Station, but at Banog station distant 2·9 miles W. N. W, $a'' = -14''{\cdot}54$; adopting this value, we find $h^s = +1^s{\cdot}9$ and the *true* Greenwich mean times of contact become

	h.	m.	s.
1st internal contact	14	17	9·0
2nd " "	18	5	32·6
2nd external "	18	32	49·6

(5)

the results (5) of course supersede (4).

J. B. N. HENNESSEY,
Depy. Superintendent 1st Grade, G. T. Survey,
In charge Computing Office.

DEHRA DUN,
9th December 1874.

Appendix to Notes on Transit of Venus across the Sun.

On 12th December 1874 I received a communication from the Reverend H. D. James M.A. describing briefly what he had seen at his station of observation. In reply I made enquiry on some additional points, to which he replied on 14th instant. Mr. James was located at Chakrata on the Himalaya mountains at a height of 7,300 feet above the sea, in Latitude N. 30° 43′ Longitude E. 77° 44′; his station is distinctly visible from Mussoorie on a clear day. The following facts are taken from his letters above mentioned, and appear to deserve being recorded, more particularly from the circumstance that but few observers of the transit are likely to have been placed at considerable heights above the sea.

Mr. James was attended by his son Henry, a young gentleman with plenty of intelligence and a commendable spirit of enquiry. The instrument used was a telescope by Smith and Beck, the property of Mr. James, object glass $3\frac{1}{2}$ inches and its focal length 4 feet: at ingress, eye-piece 60 power and field a neutral tint; at egress, eye-piece 100 power and field red: for time piece, he used his pocket watch which has a seconds hand; the watch "gained considerably, perhaps a minute in 12 hours".

Under date 9th December 1874, Mr. James states "when she (*i. e.* Venus) was about half "way on (at ingress) the sun, we both noticed a fringe of white light illuminating that rim, of "the planet which was yet on the dark sky. When she went off, we noticed the same fringe of "light, but for a much shorter time and when only about one eighth of her had passed the "sun's disc." His watch times of contact were as follows.

	h.	m.	s.
1st internal contact	7	41	20
2nd " "	11	30	15
2nd external "	11	57	25

After receipt of the preceding I wrote to Mr. James, as already stated. I stated briefly that my view resembled his; that I had seen a ring of light but no "pear drop" or other ligament at internal contacts. I gave him rough sketches of some of the ligaments described in 1769 and enquired if he had seen any thing like them. I also asked him to describe the fringe of light he had observed, more particularly.

In reply, Mr. James states under date 14th December "when about half her orb had en-"tered (alluding to ingress) my attention was attracted to the other half yet on the dark sky, "to me it was dark, hence I infer that my field was not so light as it ought to have been. "Its outline up to this time quite invisible to me, became now illumined with a fringe of white "light. I then also noticed a much fainter thinner edging of light on the outline of the limb "on the sun's disc, which soon ceased to be visible. The fringe external was rather less in "width than $\frac{1}{64}$ of the planet's diameter" * * * "The light somewhat resembled that "which we see so plainly in India lighting up the dark side of the moon 3 or 4 days old, but it "was brighter, not diffusive as that is, its inner edge being clearly marked. It remained visible "as long as there was any appreciable portion of the planet beyond the sun's circumference."

"As the time of the internal contact approached, that half of the planet which was still "entering appeared to lose its semi-circular shape and to become oval. I compared it to the "thinner half of an egg, but since I have examined several eggs and find that my comparison "would represent a distortion greater than I had intended. Just before the contact ceased the "end of the oval seemed as if it were adhering to the sun's edge, and could not get free—render-"ing it difficult to decide when the contact ceased. Another impediment in the way of accurate "timing was that the outline of Venus looked woolly and wave-like from a very annoying "tremor in the air. Hence the notes we entered were "internal contact ceased *7h. 41m. 20s.*

"quite clear 7*h.* 42*m.* As to the ligament which seemed to knit the two edges together, I am "disposed to attribute it solely to the billowy motion of the planet's outline, for it had a hairy "appearance and sun-light could be seen through it."

"In timing the remaining contacts there was no difficulty, for as the sun arose, Venus "appeared to diminish in size, her outline becoming sharply defined."

"At egress the oval shape did not reappear, but just at the moment of internal contact "there was a sort of flickering movement, as if the planet's edge had touched, withdrawn and "touched again. This was at 11*h.* 30*m.* 15*s.* At 11*h.* 33*m.* 27*s.* when nearly one *eighth* of "her orb had crossed the border, its outline was for a brief while fringed with an edging of "light."

"The flickering movement just mentioned, evidently an ocular illusion, induced by the "eye's weariness from intent gazing, was again noticed at 11*h.* 57*m.* 25*s.* when the external "contact ceased."

It will be seen that both Mr. James and I observed an edging of light around the dark limb of Venus and that we agree that it was quite distinct at ingress and less plain at egress. *I* saw this edging decidedly as an *annulus* and as stated in Part I, it was continued round the bright limb. The complete ring thus presented to view was plainly a visible atmosphere or envelope. Notwithstanding the somewhat conflicting statements, which have appeared since writing my Part I, as to the phenomena seen at certain stations; and pending the authoritative decisions which may hereafter be pronounced, it appears to me probable, that height of station, inferiority of instruments, insensibility of eye to faint lights and shadows, and other causes are likely to conspire towards producing a ligament (or *pear drop*) at the internal contacts, provided there is an atmosphere or envelope around the planet to afford a first cause.

J. B. N. H.

ACCOUNT

OF

TRANS-HIMALAYAN EXPLORATIONS

TO ACCOMPANY

THE GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA

DURING

1873-74.

Map

TO ILLUSTRATE

THE REPORT O

THE TRANS-HIMALAYAN EX[illegible]RATIONS

IN GREAT TIBE[illegible]

TO THE NORTH [illegible]

THE BRAHMAPUTRA [illegible]

MADE DURING [illegible]

1872.

Note.—The Explorer's Route is colored red.
The portion of the Route south of the Brahmaputra River is [illegible] from the Trans-Himalayan Explorations made during 1865-67, an account [illegible]ich, with a map, was published with the General Report of the Great Trigo[illegible]ical Survey for the year 1866-67.

[illegible]graphed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Doon, January 1875

Narrative of an exploration of the Namcho or Tengri Nur Lake in Great Tibet made by a native explorer, during 1872, drawn up by Lieut-Colonel T. G. MONTGOMERIE, R.E., F. R. S., &c., Deputy Superintendent, G. T. Survey of India.

During 1871 a party was organised with a view to exploring some portion of the unknown regions north of the Tibetan watershed of the upper Brahmaputra. The party consisted of a semi-Tibetan, a young man who had been thoroughly trained for the work, with 4 reliable assistants engaged from border districts; one of these latter had been employed on a former exploration in a subordinate capacity and his experience, as far as travelling in such countries was concerned, would have been exceedingly useful, but unfortunately he was unable to get more than a march beyond the frontier because the officials on the other side of the Himalayas were determined to arrest him if he proceeded further, though his ostensive object was trade. This being the case there was nothing for it but to arrange for his return and to substitute another man in his place. This was managed satisfactorily after some delay.

The exploring party then passed from Kumaon into the Tibetan province of Hundes or Gnarikhorsum. At first they got on very well but towards the end of July, when in the neighbourhood of the Mánsarowar lake, their progress was for sometime interrupted by a band of mounted robbers who had made an incursion from the east: they succeeded in evading the robbers but had to take a circuitous route by Púrung, instead of going direct to Shigatze from Mánsarowar as first arranged. The party reached Shigatze on the 24th November and remained there 12 days making inquiries as to the best route to go to the Tengri Núr lake and preparing for the journey. Sheep were the only animals likely to stand the journey, as the roads were too stony for yáks and the country was too cold for donkeys, the explorer consequently purchased 50 sheep and put all the baggage on their backs. The party left Shigatze on the 6th December marching as far as the "Naisáng" village; on the 7th they crossed the great Brahmaputra (or Sangpo) River by means of rafts and encamped at Peting village on the left bank of the river. Peting has about 30 houses. The next day they put up at Chua village. Here the explorer exchanged the silver rupees he had with him for gold which he put into hollow walking sticks prepared for the purpose. On the 11th December they reached Dongdot-lo, a village on the right bank of the Shiang Chu, a northern tributary of the Brahmaputra; here they found an official from Shigatze who rules over Dongdot-lo and the surrounding villages which are numerous. On the 13th December they reached "Chom", a village of 50 houses with a Buddhist monastery (Gonpa) on its west. This monastery or rather nunnery is occupied by women only, of whom there were about 100. On the 14th they reached "Namling" on the right bank of the Shiang Chu river; here there is a large monastery with about 500 Lámas, all men: the monastery is on a high hill, it is a place of some importance boasting of an iron bridge over the river and commanded by a strongly situated fort which is the residence of the Jongpon, or Governor, with about 500 Tibetan soldiers; Namling itself has about 200 houses surrounded by gardens with a small bazar in the centre. The "Sokpo Giájú" tribe—who bring salt—trade through this bazar which produces all ordinary provisions. The name of Namling is derived from the two Tibetan words "nam" sky and "ling" garden, the monastery being on a high hill with gardens at its foot. On the 17th December the party reached "Kholam" village on the left bank of the Shiang Chu river which was crossed by means of the iron bridge: Kholam has about 50 houses; the land round about is very productive. On the 19th they reached "Gonkiáng" a village of 60 houses with a well built monastery on rising ground. In this monastery there are about 100 Lámas ruled by a Láma of high rank, called Chúringboche, who is very much respected by the people round about.

On the 20th December the party halted at another monastery, called Rabdan Chuling Gonpa, built about 80 years ago; it is the residence of another high Láma called "Shaptung Ringboche" said to be 100 years of age who was both the founder and builder of this monastery. The people of the country say that whilst out hunting he heard a voice which told him to put down his gun and go to a certain spot where he would find unlimited riches buried in the ground, with this he was commanded to build a monastery: he had obeyed the inspiration and had ever since passed his life in religious duties. "Rabdan" means house, "chu" wisdom and "ling" garden. The Láma, when the explorer saw him, was evidently a very old man, his body so small and shrunk that when sitting his knees projected a great deal above his head.

From the time the explorer left Namling on the 14th December it was so cold that the mercury of his thermometer did not rise out of the bulb till after 9 or 10 in the morning. The streams were all hard frozen. The wind moreover blew so hard that their tent was torn by it and they had consequently to make a halt of 5 days in order to repair the damage. On the 26th December they marched on and reached Gunje; the people of this village said white bears called "Tik-dumba" were very common from thence to Namcho lake and committed great havoc amongst their cattle.

On the 27th December he reached Naikor which has about 30 houses and some cultivation; beyond Naikor there was no more cultivation, and the only inhabitants are nomadic, going by the name of Dogpá; they graze sheep, goats and yáks.

On the 28th December the explorer encamped at "Chutang Cháká" where there are some 15 hot springs, whose water was found to be at a temperature of 166° Fahrenheit, boiling water at the same place only rising to 186° Fahrenheit. There were 8 baths supplied by these springs, the baths were put at some distance from the springs so as to allow the water to cool sufficiently for bathing. The water has a smell of sulphur. There were a number of "Dogpá" tents at a short distance from the springs.

From the Brahmaputra river near Shigatze up to these springs the country is called "Shiang Lungba" and that to the north "Lahú-Lungba."

On the 29th December the "Chapting" encamping ground was reached; here there were more "Dogpá" tents; the road was so slippery with ice that one of the men fell and broke a thermometer. On the 30th December they arrived at "Peting Chuja" near which, on the right bank of the Lahú Chu river, there is a large stony place about 120 paces in length from which about a dozen columns of hot water issue, these rise to a height of 40 or 50 feet, and produce so much steam that the sky is quite darkened with it, the noise moreover was so great that they could not hear one another speaking; the water of these jets was found to be 176° Fahrenheit. Similar jets of water were noticed issuing from the middle of the river, shooting up to 40 or 50 feet in height and evidently at much the same temperature as those on land, as they produced clouds of steam, and the river was free from ice for a quarter of a mile below them though everywhere else both above and below it was hard frozen. The Jáwar Gonpa monastery lies about 3 miles to the east of these springs. The explorer went to the monastery which he found had a number of highly ornamented idols, in front of which were arranged a number of petrified stones called Naidhowas, these are in various shapes, such as hands, shells, &c., and are objects of worship as well as the idols. Jáwar is the name the Tibetans have for Suket-Mandi in the Panjáb hills, N. by W. of Simla. This according to a tradition was given in honor of a daughter of a Rája of Suket-Mandi who was supposed to have married "Laban" one of the idols.

On the 31st December the encampment of Sulung Sumdo was reached, here they found some 40 tents. On the 1st January they halted at Sulung which boasts of 50 Dogpá tents. The Dogpás said there were no regular encampments beyond Sulung, the only people about being thieves on the look out for plunder, against whom it would be necessary to be on their guard.

On the 2nd of January the explorer reached, "Naisum Chuja." Chuja or chusa means source of hot water springs. The name is given to the place from the great number of hot springs which there are here on both sides of the Lahú Chu river. The water from these springs is so hot that the river is not frozen for about 3 miles below them though every where else it was frozen over. On the right bank of the river there are two very remarkable hot springs which throw up a jet of water over 60 feet in height; the water in falling again freezes and forms pillars of ice which are nearly up to the full height of the jet. These pillars are about 30 feet in circumference and look like towers with holes at the sides just as if they had been made artificially. The water is thrown up with great violence and noise. The thermometer when put in the water inside the pillars stood at 183° Fahrenheit the boiling point there being only 183°·75.

The party was delayed at Naisum Chuja for 3 days owing to one of the men getting sick; it is said to be a great place of worship or pilgrimage. Owing to cloudy weather the explorer was unable to take any astronomical observations.

On the 6th January they reached Dung Cháká 15,700 feet above sea level where there are more hot springs but not of such high temperature as the last, their water showing only 130° Fahrenheit, while the boiling point was 183°: about 10 miles to the east there is a lofty snowy peak called "Jhomo Gangar" somewhat of the same shape as the Kailás peak near the Mánsarowar; it is a noted object of worship being considered as a female divinity. On the 7th January they encamped at the foot of the Khálamba Lá crossing over on the 8th, the highest part of the pass being 17,200 feet above the sea and water boiling at 180°. The crossing was very difficult owing to a heavy fall of snow which made the descent on the opposite side very dangerous. The only fire that they could make after crossing was from goats' dung with which they managed to warm up a brew of tea. The next day the explorer returned to the pass in order to re-observe the boiling point, not being quite satisfied that the water was properly boiling the first day that they crossed over. He was again troubled with snow and when he got back to camp was half dead with the intense cold, and did not recover till he had drunk a bowl of hot tea. The encamping place is called Dung Nagu Cháká; there were several hot springs round about, the water in them raising the thermometer to 180°, while boiling water only raised it two degrees higher.

On the 10th of January they reached Kiang Lá and on the 11th Dokmar encampment, where the Dogpás generally keep their sheep, goats, &c., during the summer. On the 12th they encamped on a plain and on the 13th reached the "Ghákiká" camping place from whence they got a view of a very large lake which they found was called by the Tibetans "Jáng Namcho Chidmo"

and supposed to be called Tingri Núr in the Tartar language. A camp of several tents was seen to the east at a place called Dungche. As a road was seen to branch off from this camp two of the men were sent in disguise as beggars in order to inquire about the road and as to why a camp was kept there; they found the camp all but deserted the only occupants being an old man and a woman who were seated in one of the tents: the man said the tents belonged to Dogpás who had concealed all their property, women, children, &c., while the men themselves had armed and gone out to meet a band of robbers who they had heard intended to plunder them. As to the road they said it went to "Lhásá" by the "Ninjinthanglá" to Jáng Hiangpa Chan Gonpa (monastery) and thence by the Tulung Chubu Gonpa (monastery) to Lhásá.

One mile north of Ghákiká the road crosses the Ghákiká Chu a large river which coming from the west flows into the "Jáng Namcho Chidmo" lake about 12 miles east of the road. The river though very wide was completely frozen over; in the summer it is said to rise very much.

On the 16th January after crossing the Ghákiká Chu river the explorer reached a place called Chákrí which is surrounded by a 10 feet high wall enclosing a space about 200 paces by 200 paces. There were several houses of sundried bricks inside the wall but they were all in ruins; the place was said to have once been the residence of a man of some rank. As a great deal of snow was falling the explorers were very glad to take advantage of the shelter which the ruins afforded. On the 18th they arrived at Simjam where they found about 70 Dogpá tents; as robbers were known to be in the vicinity every tent was guarded by an armed man. The robbers were said to come from a district called Jámaáta De which lies to the north. Jámaáta De is said not to be under Lhásá and the inhabitants consequently plunder the Lhásá districts whenever they are in want, as they often are in consequence of the severity of the climate which kills off their cattle whenever there is an extra heavy fall of snow. Simjam being one of the nearest places to these freebooters has very often been plundered.

The party were detained two days at Simjam owing to heavy snow and did not start again till the 21st of January, when they marched to "Tárá" ~~for the most part along~~ the shores of the great "Namcho" lake which was completely frozen over and seemed to extend to a great distance eastward. The next day they continued their march along the shores of the great lake and reached the monastery called "Dorkiá Lúgu Dong" situated on a small hill overlooking the lake. "Dor" means a rock "lúgu" a sheep, "dong" a face. The monastery looking something like a sheep's head:

A chief Láma lives here with some forty ordinary Lámas. The monastery commands a splendid view of the lake and surrounding snowy mountains which were more especially grand to the southeast.

The lake is a magnificient sheet of water and near Dorkiá it has the advantage of having an island close at hand which sets off the scenery. The island is about a mile long and half a mile in breadth; it has a hill about 400 feet high in the centre which is crowned by a temple of the goddess "Dorje Phámo". The explorer determined to make a complete survey of the lake and he consequently deposited his property in the monastery with 3 of his men, being afraid of robbers, having done this he started off with 3 other of his men; on the 24th January they reached Ringa Do on the margin of the lake, here there is another island, called "Kuhi Ne Dobo" close to the shore, which is about 1½ miles in length by about 1 mile in breadth.

On the 25th they reached Jádor Gonpa (monastery) here they saw 3 pyramids or cones of earth or sundried mud each about 500 feet in circumference rising to a considerable height. The explorer went under these mounds by an artificial passage and found that one of them was open in the centre. The people say that they were originally all closed and that when a certain very devout Láma, who used to worship under one of these mounds, died he was taken up into heaven through the opening. The Jádor Gonpa has about 50 Lámas. Near the monastery there are a great many fossil stones which are held in veneration, they are called "Naidhowa". The explorer saw a gigantic doorway cut in the rock through which the Lámas say the god "Ninjinthanglá" passes, its height is about 25 feet. Owing to heavy snow the explorer was detained two days at "Jádor".

On the 29th they reached Nángbá Do which is also on the shore of the lake close to some small hills which are considered to be sacred. The next day they halted at "Lángdang"; here they found the "Shukpá" bush very abundant. On a low hill there is a temple of a god called Chogo Lá. On the 30th they got to Dakmar and passing Thuígo Sumna shrine they reached Nai Chu Sumna on the 31st. On their way they crossed the Nai Chu which is a very large stream, being the largest that flows into the lake, it comes from the east. At the time the explorer crossed it was 40 paces in width and completely frozen over.

On the 1st February the explorer reached the Tashí Doche Gonpa, a monastery which is on a low hill near the lake, it has 35 Láma monks. To the southwest of this monastery there are a number of magnificent snowy peaks which are called the "Ninjinthanglá" peaks. The Lámas say the highest peak is a god and that he is surrounded by 360 smaller snowy peaks which act as his servants.

To the east of "Tashí Doche" there is another mass of high peaks called Nuchin Gásá which appeared to the explorer to rise higher above the Namcho lake than the Kailás peak

does above the Mánsarowar lake. The whole of these peaks were very imposing as seen from the monastery which also commands a full view of the whole of the lake. Though the water of the lake is so salt as to be unfit for drinking it is nevertheless quite frozen over in November, the lake being about 15,500 feet above the sea; when the explorer saw it the surface looked as if it was made of glass, it is said to remain in that state till May when the ice breaks up with great noise. The lake contains fish, and quantities of small shells are found on the banks. The lake itself is a great resort for pilgrims.

On the 3rd they halted near a small river; on the 4th they reached an open plain at night and were put to great straits owing to a heavy fall of snow. They had left their tent behind at Dorkiá and no shelter being available they had to clear off the snow and lie on the ground without any fire; they thought the cold would have killed them, but they managed to survive the night through; in the morning they found they were well covered with fresh snow. On the 5th they went on to the Ghákiá Chu river; it was snowing all the time and they were forced to camp out again without any fuel or covering and passed another very miserable night. On the 6th they saw the sun again and were able to get some fuel and to make themselves tolerably comfortable, but whilst crossing at the side of the lake near a small stream, (the Simjam Chu) one of the men fell through the ice which was covered with snow and would have been drowned had he not got hold of another man who pulled him out again. The man's clothes froze hard directly he got out, and he was only brought round by means of a fire which they at once lighted.

On the 7th February they reached the Dorkiá monastery from which they originally started, having been 15 days in making the circuit of the lake. They halted 3 days at the monastery and started off on the 11th, getting that day as far as "Ringa Do;" on the 13th they reached the Jádor Gonpa before mentioned and on the 14th Nángbá Do. Here the explorer heard there was a lake called Bul Cho about 6 or 7 miles to the north, he accordingly climbed a peak in that direction and saw the lake. He estimated it to be about 6 miles by five. A kind of borax is found by and in the lake, it is called "Bul" and hence the name. This borax is used by the inhabitants of Lhásá and Shigatze as a spice for meat, for tea and for washing clothes, bathing, &c. It is carried away by the traders in great quantities.

On the 15th they reached Lángdang, on the 16th Dakmar, on the 17th the plain of Cháng Pháng Chujá where there are several hot springs in which the thermometer rose to 130°. On the 18th as they were about to start some 60 armed men arrived on horse back and began plundering their property and in spite of their entreaties took away everything except the instruments which they said they did not care to keep in case the authorities should find them on them and ask how they came into their possession. After a great deal of begging the robbers gave them back a piece of cloth each with two sheep and two bags of food, a cooking vessel and a wooden cup to each man; with these they had to be contented, the robbers saying if they troubled them any more they would kill them.

The explorer had intended to make his way from the Namcho lake to the north as far as the city of "Sinning," but after the robbery there was no possibility of doing that and indeed they were so far from habitations that it was a question whether they could exist, and there was nothing for it but to march as quickly as they could to the south in the direction of Lhásá where they were likely to get into inhabited ground soonest. The day after the robbery they halted in order to consult as to the best course to follow. On the 20th February they went as far as the banks of the "Nai Chu" river; here one of the men got sick and they were obliged to remain there all the 21st, their food consisted of one pound of flour and hot water, they had moreover nothing to cover themselves with, the robbers having taken the tent, and were exposed to the snow and wind which blew very hard.

On the 22nd they reached Dam Niárgan Lá. The explorer says that he had got so weak that he took much shorter paces than he had hitherto done. On the 23rd they ascended the Dam Niárgan Lá pass, after crossing they decided to kill one of their two sheep as they had exhausted all their flour; at the same time seeing tents in the neighbourhood all the men went out to beg and after a long round came back with 6 pounds of flour and began to feel more hopeful, on the 25th another man got ill and they were obliged to halt again.

From Dam Niárgan there is said to be a road to Lob Núr and to "Jilling" or "Sinning." From "Dam Niárgan" it is about 10 days journey to Nákchukhá, a place that has a bad reputation as to the number of robbers who prey upon travellers; from thence it is about 45 days' journey to Sokpohuil which is quite a barren country infested however by robbers; after passing Sokpohuil the inhabitants are more civilized and are said to be very kind to travellers.

The Lob Núr (? Koknúr) lake is in the Sokpohuil territory, and close to it is the town of Kharká. It is about 15 days' journey from Sokpohuil to "Sinning" city, where a Chinese Amba, a man of considerable authority resides. "Sinning" is described as being very superior to "Lhásá," good horses, sheep, &c., are procurable and the shops are well supplied with silk, woolen articles, carpets, &c.

On the 26th they halted under the Cháná Lá pass, the country up to this point was called "Dam Niárgan." On the 27th they halted at Angchusa where they noticed 6 Dogpá tents. On the 28th they reached "Láchu Sumna" the extremity of the "Bádam" district which begins at Cháná Lá.

The "Urirong" district extends from "Láchu Sumna to "Dhog Lá." On the 29th they reached Siwalungi Ritu (Gonpa) monastery which has some 60 Láma monks. Here the height was observed by boiling point, but owing to the loss of his quick silver, when robbed at Cháng Pháng, the explorer was unable to take Latitude observations he however hoped that on reaching Lhásá he would be able to borrow sufficient money to enable him to refit and to return to this same place on his way north east to China.

On the 1st of March he crossed the Dhok Lá pass encamping on the other side, the district of "Jáng Tálung" extends from the Dhog Lá to the Chak Lá pass. On the 2nd they reached the very large monastery called "Jáng Tálung" which has 2 head Lámas with about a thousand monks. Here they halted during the 3rd in order to rest and examine the monastery; inside they found a large number of images carved in the walls the whole of these were adorned with gold. The road from Lhásá to Lob Núr (?) and "Jilling" ("Sinning") passes about one mile south of the monastery. The Sinning Kafilas pass by this route with their camels laden with merchandize. On the 4th march he crossed the Chak Lá pass and encamped at its foot on the opposite (south side) near the village of "Lángmo" where they saw the first signs of cultivation that they had met with since the 29th of December. On the 5th they reached "Jhokár Churtan;" on the 6th Naimár village which has about 20 houses surrounded by a number of smaller clusters of houses. On the 7th they reached the monastery of "Nehlin Dák," on the 8th after crossing the Phembu Gong Lá pass they halted at Lingbu Jong. The Phembu district ceases at the pass of that name. On the 9th of March the party reached Lhásá they were excessively glad to get back to a civilized place again where they would at any rate have no chance of being starved as they were at one time likely to be.

Though the Lhásá people were hospitable enough the explorer found there was no chance of his being able to borrow sufficient money to enable him to march to "Sinning" as he had intended; with the greatest difficulty he managed to borrow 150 Rupees from a trader who was going to Gartok, but he insisted upon the explorer accompanying him and in addition took his aneroid barometer and compass as a pledge for the money, the aneroid which was a large one he apparently took for a magnificent watch and at the end of the journey the explorer's messenger who was sent with money to redeem the instruments had some difficulty in recovering them. Having the command of so little money the explorer decided upon returning to India and after a long and difficult journey reached the Head Quarters of the Great Trigonometrical Survey in safety.

Memorandum by Lieut.-Colonel T. G. Montgomerie, R.E., F.R.S., &c., on the results of an exploration of the "Namcho" or Tengri Núr Lake in Great Tibet made by a Native Explorer.

Amongst other attempts to explore the various countries beyond the borders of British India, I have always borne in mind the necessity to explore the vast regions which lie to the north of the Himalayan range, from E. Longitude 83° to E. Longitude 93°, and I have consequently, from time to time, tried to get more information as to this *terra incognita*; but since the Pundit made his way from Kumaon to Lhásá, I had not till lately succeeded in getting much advance made to the north of his line of explorations, though a good deal was done to the north of the Mánsarowar Lake. One explorer made his way from Rudok on the Pangkong Lake to Thok-Jalung and thence back to the Mánsarowar, passing quite to the east of the great "Kailás" peak. The same explorer subsequently made his way to "Shigatze", but he was unable to penetrate to the north of the main course of the upper Brahmaputra. Though disappointed with this I continued to try and get an explorer to penetrate into those regions, and after many failures I have at last the satisfaction to be able to report that some progress has been made in exploring to the north of Shigatze and Lhásá.

The accompanying narrative gives the details that I was able to gather from the explorer.

As usual the party was troubled at the frontier; but once fairly in Tibetan territory they had no difficulty in making their way down the upper Brahmaputra to Shigatze, at least had no difficulty that would not equally have affected ordinary inhabitants of the country. They found no good opportunity of penetrating to the north till they reached "Shigatze;" there they, as directed, made inquiries about the Tengri Núr Lake. They found that there was a regular route to this lake frequented by traders in borax, salt, &c., and also by pilgrims; they consequently decided to try and make their way there in the character of pilgrims,

taking with them a small supply of goods with a view to meeting their wants on the road by barter, the ordinary custom of such pilgrims.

They were told that sheep were the only means of carriage that would answer and they made their arrangements accordingly, purchasing some of the large long-legged sheep with the usual bags for loading. They marched down to the Brahmaputra, crossing that great river by means of rafts; this point was about 11,200 feet above the sea. Ascending the Shiang Chu tributary of the river the party day by day got into still higher ground, until they reached the Khálamba Lá pass, 17,200 feet above the sea, and there crossing over from the basin of the Brahmaputra they descended into the basin of the Tengri Núr Lake, which was found to be about 15,500 feet above the sea.

For 8 days after leaving the Brahmaputra the explorer marched from village to village, passing many Buddhist monasteries and some nunneries with numbers of small villages surrounded by a good deal of cultivation. Naikor was the last village with cultivation; northward they were informed they would find nothing except the camps of "*Dogpás*", as the nomadic people of that part of the country are called; and they were warned to be on their guard against the white bears which were said to commit havoc amongst the cattle, sheep, &c. The explorer was well acquainted with the brown bear of the Cis-Himalayan districts and he believed this white bear to be a different animal and not the brown bear in its winter coat.

During the great part of his journey to the Namcho Lake the explorer found the streams all hard frozen, and he was consequently much struck by the number of hot springs that he met with and more especially by the great heat of the water coming from them, his thermometer showing it to vary from 130° to 183° Fahrenheit, being generally over 150° and often within a few degrees of the boiling point, being in one case 183° when the boiling point was 183¾°. The water generally had a sulphurous smell and in many cases was ejected with great noise and violence; in one place the force was sufficient to throw the water up from 40 to 60 feet. These springs in some respects seem to resemble the geysers of Iceland; in winter they are very remarkable in consequence of the water when falling being converted into ice which forms a pillar of ice round each jet. The quantity of warm water which escapes from below must however be very considerable, as the streams into which they drain were free from ice for some distance below where the warm water comes in, though every where else hard frozen.

The great lake, which at distance was called the Tengri Núr, was found on nearer approach to be called Namcho or Sky-lake (Nam=sky and Cho=lake) from the great altitude at which it is. It proved to be a splendid sheet of water about fifty miles in length by from sixteen to twenty-five miles in breadth. It receives the water of two considerable rivers and several minor streams, but has no exit; the water is decidedly bitter, but owing to intense cold it freezes readily and at the time the explorer saw it was one continuous sheet of ice.

To the south the lake is bounded by a splendid range of snowy peaks, flanked with large glaciers, culminating in the magnificent peak "Jáng Ninjinthanglá" which is probably more than 25,000 feet above the sea. The range was traced for nearly 150 miles, running in a northeasterly direction. To the north of the lake the mountains were not comparatively speaking high, nor were there any high peaks visible farther north as far as the explorer could see from a commanding point which he climbed up to. He only saw a succession of rounded hills with moderately flat-ground in between them. Immediately north he saw a lake of about 6 miles in length which he was told was called Bul Cho from the borax (bul) which is produced there in large quantities, supplying both Lhásá and Shigatze with most of the borax that they require.

The "Namcho" Lake is considered to be a sacred place like the Mánsarowar Lake, and although at such a very great distance from habitations and so high above the sea it boasts of several permanent monasteries and is visited by large numbers of pilgrims. There are several islands in the lake, two of them large enough for monasteries: at the time the explorer was there the Lámas on the islands kept up their communication with the shore by means of the ice, but he did not hear as to what was done in summer. Fish are said to be abundant and modern lake shells were found on the shore as well as fossil shells, which were very numerous and of all sizes; a few of the smaller ones have been examined by Mr. Oldham, the Superintendent of the Geological Survey; he thinks they are not older than cretaceous and are probably, nummulitic "none of them actually agree with the Sind and Panjáb nummulitic "fossils yet described, but they come near them; there is a small Fusus, two specimens at the "upper whorls of a Vicarya or Cerithium with a cast of probably the same species, also a cast "or internal mould of a Tapes." The specimens sent to Mr. Oldham were however too few and too badly preserved to enable him to give a decided opinion about them, I had unfortunately started for England before I knew this, otherwise I should have sent him larger specimens. The first opportunity will be taken to have them more thoroughly examined as also the few modern shells that reached me. The Chief Pundit on his first journey remarked on the stone bones, shells, &c., that he saw in the Lhásá bazar where they are sold in great quantities for medicine, charms, &c. The explorer had also noticed them in other parts, and there is very little doubt but that Tibet will prove to be very rich in fossils and will amply repay the first European that has the luck to penetrate into the country.

The explorer was only able to bring back some of the smaller specimens.

In most places the margin of the lake was utterly desolate, but near Lángdang the Shukpá bush was abundant. In another place there was a little vegetation near some hot springs.

The explorer's examination of the lake was unfortunately brought to a sudden close by a band of robbers from Jámaáta De the district north of the lake. These robbers stripped the party so completely that they were forced to make their way to Lhásá as fast as they could. They were very nearly starved to death and underwent very great hardships before they got there.

In Lhásá they managed to raise a little money by pawning their instruments, the aneroid which was a large one proving very serviceable, as it was mistaken for a gigantic watch and was valued accordingly.

The proof of the existence of a great snowy range to the north of the Brahmaputra is interesting, the Himalayan system even at that distance, say 160 miles from its base in the plains of India showing no signs of getting lower. The Lámas of the Namcho Lake described the country to the north as being very much the same as that round the lake, and that it was only after advancing some 60 marches farther northeast that there were any signs of a more civilized country. Jámaáta De (de means district) immediately north of the lake is not under the Lhásá Government. It must be even more elevated than the country about Namcho, as the inhabitants are said to have great difficulty in keeping cattle, losing numbers every few years owing to heavy and continuous falls of snow. The Jámaáta people are a lawless set and always try to make up for any such losses by robbing their neighbours about Namcho, Simjam, &c., and where cattle thrive better. Lob Núr was said to be 2½ to 3 months journey north of Namcho: it was not clear from the explorer's account whether this was the Koko Núr Lake or some other lake more to the west. The route ran north from the east end of the Namcho, leaving at a camping place called Dam Niárgan. From this point Nákchukhá is distant 10 days journey and has a very bad reputation as to robbers. From Nákchukhá it is 1½ month's journey, to Sokpohuil over a most barren country infested by robbers, but owning no regular inhabitants of any kind. Sokpohuil district is said to be not very far from Lob Núr, near which is the town of Kharká, the residence of a great Láma called Jipchun Ringboche who rules over the Sokpohuil country. Kharká is said to be above 15 days journey from Jilling or Sinning-fu, the large city near the northwestern end of the great wall of China. Jilling was well known to the people about Namcho who admit that it is larger even than Lhásá itself.

The great northern road called the Janglam, which runs far north of the course of the upper Brahmaputra river, passes by the Namcho or Tengri Núr Lake and from thence by Shellifuk Lake to Rudok on the Pangkong Lake east of Leh the capital of Ladák. The route followed by the explorer from Dam Niárgan to Lhásá is the route by which Messrs. Huc and Gabet must have approached that city. The explorer thought he would have been able to make his way along it by the Koko Núr and thence through Sinning-fu to China if he had the necessary funds. Another attempt will if possible be made to do this, as even the slight amount of information gained respecting it is encouraging and it would be a great thing to get a route survey between Lhásá and Sinning-fu, so as to connect our Indian Trans-Himalayan Explorations with a place that has been fixed by the regular survey operations of the French Jesuit Missionaries.

The route survey extends over 320 miles of what has hitherto been veritable *terra incognita*. Latitude observations were taken at 7 places, and heights by observations of the boiling point and of the aneroid at 24 places. The geography of an area of about 12,000 square miles has been elucidated and one northern tributary of the upper Brahmaputra has been thoroughly explored, thus giving us some idea as to how far back the northern watershed of this great river lies. 10

The Namcho is evidently the lake referred to in old maps as the Tengri Núr. The explorer actually went round it and found that it had no outlet though fed by two large and a number of minor streams.

The length of the explorer's pace has as usual been computed by means of the differences of observed latitude, &c., and was found to be very fairly accordant on different sections.

The difference of longitude between Shigatze and Lhásá as determined by this route survey is nine minutes less than that deduced from the Chief Pundit's survey. The latter was however a much more direct line and the value therefore has been retained. The difference being say 9 miles in 320 miles or about 3 per cent is a satisfactory proof of general accuracy.

The heights by observations of the boiling point were satisfactory, but those by the aneroid show that the index must have shifted very much; for although agreeing closely with an ordinary mercurial barometer up to 7,000 or 8,000 feet above the sea, yet in the neighbourhood of Shigatze (at Peting), which was previously known to be about 11,000 feet above sea, the aneroid observation indicated an altitude of nearly 4,800 feet higher. The aneroid observations on the average give altitudes 4,631 feet higher than those by boiling the thermometer, a most disappointing result, the aneroid being one that was carefully tested under an air pump at Kew when it was found to agree at every inch of pressure from the normal height down to 11-inches.

A similar difference was given by another aneroid that was sent up to the Thok-Jalung gold fields; this was supposed to have arisen from some accidental fault.

Captain Basevi when employed in the elevated ground in the south and northeast of Ladák was supplied with a similar aneroid and noted in his memoranda that the observations taken with it were quite unreliable at great altitudes, as he found that even by gentle tapping on the case the index varied its reading and was always moveable in that way no matter how long he remained at a point.

The only conclusion that can be come to, from the three trials referred to, is that in their present shape aneroid barometers cannot be relied on alone at great elevations until they have actually been tested, and they should always be at any rate supplemented with either occasional observations of an ordinary mercurial barometer or of a boiling thermometer, at any rate until some satisfactory proof of their reliability has been given, the errors apparently not showing when the aneroid was at rest and kept at much the same temperature.

It will be noticed that the explorer actually went along a small portion of the great Brahmaputra river below Shigatze, thus adding to our knowledge of its actual course; no iron suspension bridge was however seen there such as "Turner" supposed to exist near Shigatze. The explorer was much struck with the magnificent glaciers to the south of the Namcho or Tengri Núr Lake and they will no doubt prove to be very extensive, as the man is a good judge of their size being well acquainted with Himalayan glaciers near India.

Altogether the explorer has done very good service, and in this first altogether independent expedition has shown a large amount of skill, observation, and determination. I trust hereafter he will still farther distinguish himself.

Extracts from an Explorer's Narrative of his journey from Pítorágarh in Kumaon viâ *Jumla to Tadum and back along the Kali Gandak to British Territory.*

After receiving my instructions and the necessary instruments I left Dehra for my home in Kumaun. While there cholera broke out in the village and attacked me and several members of my family, of whom my wife and 3 others died and I was prostrated for 2 months.

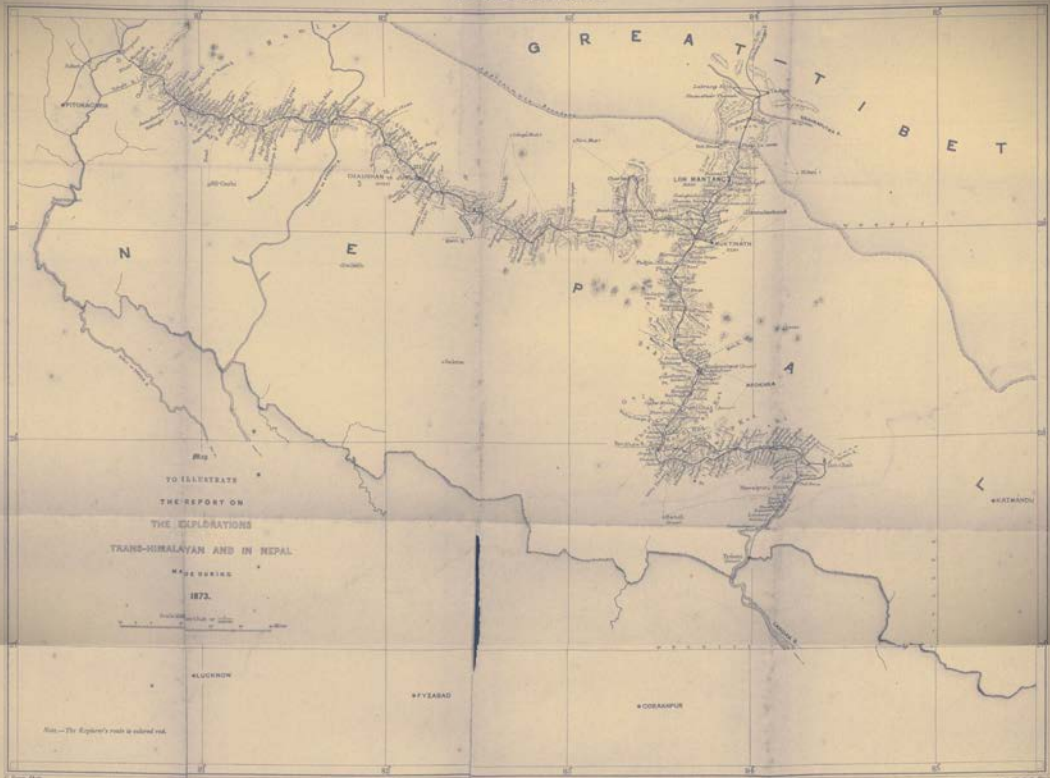
On the 1st July I started with my survey from Pítorágarh and on the 3rd day reached Askot. At Askot there resides a man named Puskar Sing Rajwar whose people are frequently passing into Nepál and I went to consult him as to which would be the best place to cross the river Káli, telling him I was a physician on my way to Jumla. I learnt from him that as the rains had set in the ropes by which the river is crossed were put away to keep them from rotting, but that if I went to Ráthi which was higher up the river I might there have a chance of crossing. I accordingly did so and reached Ráthi on the 6th. As there was only a rope by which the river is crossed and men suspend themselves by their hands and feet and bear such loads as are to be carried over on their chests, I had no nerve for it, so had a sling made for myself and was drawn across in it and stopped at Bargáon in the Don pattí, in Nepál on the 7th. Bargáon has 50 houses and is about the largest sized village in the pattí.

On the 8th I travelled through a tract but little inhabited and along a difficult road and halted for the night without provisions at a deserted sheep fold.

On the 9th after another yet more difficult journey I arrived at Maikholi (2 houses.)

On the 10th I reached Shipti village (30 houses) having crossed the Kotidhar pass 5,793 feet above sea, and the river Tatigár on the way. Although Shipti is in the Don pattí, on account of its size and importance it is usual to include the villages in its neighbourhood in a pattí which is called after it.

On the 11th I went to Shiri in the Marma pattí. The villages of this pattí are all in the valley of the Chamlia river. Cultivation is extensively carried on in it. The villages are situated where the hills have gentle slopes and the land which is terraced is irrigated by small channels from the Chamlia. Fish which abound in the river, are caught, dried and stored by the villagers in large quantities, for home consumption; they are eaten by all castes. I here intended crossing the river, but found the ropes broken: I went a couple of miles further up and found crossing ropes and passed over. The road for the 2 miles up the river and back to the main road on the opposite side was so difficult that it took me half the day to go over it. Halted at Matiál; formerly a road from Doti to Taglakhar led along the Chamlia through



Map
TO ILLUSTRATE
THE REPORT ON
THE EXPLORATIONS
TRANS-HIMALAYAN AND IN NEPAL
BY
1873.

Note.—The Explorer's route is colored red.

Photolithographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Dun, February 1875.

this pattí and by a pass across the Marma snowy range. It was given up a long time back owing to a dispute with the Taglakhar people. The snowy range is not more than 14 or 15 miles N. E. of the river.

On the 13th, I marched to Karálá in the Búngnang pattí. This march consists of a difficult ascent to the Machaunia-lekh pass, during which no water is to be had, and of a descent. At the summit of the pass the birch and juniper grow, and lower down oak and "ringal" (hill bamboo) and "pangar" (horse chestnut). The lands of the villages in this pattí are well cultivated. I halted at Karálá 5,326 feet above sea level on the 14th owing to rain. On the 15th, I started, crossing and recrossing the Karálágár till it joins the Sangár, a larger river which comes from the snow but which is called Karálágár below the junction. I crossed the Sangár stream by a wooden bridge and continued along the left till I came opposite to Batusherá which is on the right bank of the Karálágár at its junction with the Nabliagár. A road from these parts to Bias goes along the left bank of the Sangár and crosses the snowy range by a high pass.

I procured a pass to Bajangayá from the Thanadar of Batusherá and by midday on the 15th I got to the Kálágár river which joins the Karálágár, and is crossed by the people of the country by ropes, but slings were at hand for those who, like myself, had no nerves for the ordinary way of crossing. I stopped for the night at Bipur on the other side of the river. From Karálá the road lies through villages and cultivated land but no forests.

On the 17th, I crossed the Karha pass, and reached Jakhora village. On the ascent to the pass there are two villages Ranlekh and Kálákáná.

On the 18th, I crossed the Kansia pass and put up for the night at Sain village in the Bajangayá pattí. The road was good, not fit for riding but very fair for walking.

On the onward journey and a little short of a mile from Sain is a temple of masonry on a well cultivated and irrigated spot at the junction of the Saingár and Khatiyarigár both small streams, the former coming from a north-westerly, and the latter from a northerly direction. On the road about ½ a mile further on is Pujári, a small village of 5 or 6 houses inhabited by brahmins, the priests of the temple. Crossing Khatiyarigár and another smaller stream of same name I at midday reached Biasi, a village consisting of 10 or 12 houses to the north of Bhajangayá about ¼ mile. Bhajangayá is an old fort out of repair. Biasi is 5,490 feet above sea level and on a level with Bhajangayá Fort.

The fort was formerly of a circular form and about ½ of a mile in circumference. It consists of dry stone walls about 10 feet high with two brick and mud 3 storied houses, with sloping roofs, formerly the residence of the Rájá and members of his family, built within the enclosure. There are about 16 houses with mud walls and thatched roofs built on the outside of the walls inhabited by the Rájá's slaves: a small spring to S. and E. of fort about 500 feet below and another to west and a short distance supply drinking water.

Slavery exists here and throughout Nepál all castes being sold into slavery, the father having power to sell his children; but on being sold individuals lose their caste. It is reported however that Jung Bahadur has intentions of suppressing this practice. On the 22nd, I left Bhajangayá and at midday came up to the Bargujál ghát on the Seti river and about 4½ miles from the former place. The road from Taglakhar to Sil-Garhi and Doti which follows the course of the Seti crosses at this place from the right to the left bank by a rope bridge 180 feet long and about 20 feet above water. The river comes winding from a northerly direction to this place, and from the snowy mountains distant about 3 days march. Between this and the snows is Humla pattí from which hawks, black minas and musk pods are brought for sale to Baramdeo Mandi and Gola Ghát Mandi.

From the ghát my road lay along the left bank for about 2½ miles, and to where the Chanakhola, a river formed by spring water, joins it and then followed up the latter, crossing and recrossing it occasionally. I halted for the night at Majh one of the five villages of Chana pattí, which includes the valley drained by the Chanakhola.

On the 23rd, about midday I left the Chanakhola where it is met by the Jhalaragár, crossed a pass over the Than ridge which was covered with oak and chestnut and entered Bájru pattí and remained at Dogra. Bájru fort, where the Rájá lives is on the summit of a hill about 5 miles from this in a south-easterly direction and on the same side of the Dogragár. It is smaller than Bhajangayá fort being about 500 paces in circumference and contains one house and is surrounded by oak trees; no cultivation was to be seen about it. There was a good deal of excitement in this place, caused by an order of Jung Bahadur for raising troops. Places which formerly supplied 100 soldiers were now required to give 150 and such as were not formerly required to furnish them were now to raise men according to the revenue paid in by them to the Government. Four hundred men used to be quartered at each of the 3 places Dandalidhura, Sil-Garhi and Dailekh; there are now 600 men at each place, that is half as many again, and at Sil-Garhi arms are now being manufactured.

On the 24th, I crossed a ridge coming from the Than ridge. Before leaving its summit I came upon a deep round hollow filled with water, about ½ a mile in circumference. The water is blue and is said to contain fish though I did not see any: there is no visible supply of water to the tank. To the east and at the edge of the water is a small temple of masonry,

called Thábur Debí. In the month of August at the time of full moon the temple is visited by people of the neighbourhood. The hills about here are covered with oak and rhododendron. About midday, having descended to the Kunragár, passed through the village of Máitoli about 4 miles from the temple and tank, and followed the stream I sighted Kunragarhi on the wooded summit of the ridge to the south of the Kunragár; although called "garhi" there is no fort and all that can be seen are two stone walled, thatched roofed houses where the Rájá resides. The hill is rugged and covered with oak and rhododendron trees and about 1,200 feet above the stream. The so called Rájá is rather a zamíndár who collects the revenue of the Kunra pattí. I stopped for the night at Sudap in the Kunra pattí, the road kept to the left bank of the Kunragár to this place. This pattí has a few villages far removed from each other, there being only one on the road between Máitoli and this. The road was difficult.

On the 25th, I left the Kunragár, which flows eastwards into the Buri Ganga also called Bhaunera about 3 miles and crossed the Pinalekh ridge, the boundary between the Kunra and Jugárá pattís, and came into the village of that name in the latter pattí (25 houses) 5,781 feet above sea level. I left this on the 3rd August, and descended to the River Bhaunera or Buri Ganga about 2½ miles below. This comes from the snowy mountains which are seen to the north-east about 16 miles distant. The river at this time of the year is about 150 feet wide, and 8 or 10 feet deep, with a rapid current. It is crossed at this place by means of a rope, a road following the course of the Bhaunera, goes to Sánpia ghát on the river lower down. To the south of the place where I crossed the river is a high peak on a snowy ridge under which at the height of the ridge is Malka Debí temple, well known and visited by pilgrims from Kumaun and Garhwál as well as from Nepál, during the time of full moon in August. There are approaches to the temple from all sides. From the river I crossed a spur about 1,000 feet high and encountered the Mártorigár a tributary of the Bhaunera a little lower down. This stream though not containing any of the drainage from the snows has deep water and is crossed by wood being thrown across it. About 6½ miles further up the stream is Jili consisting of 10 or 12 houses where I remained for the night. The village which gives its name to the stream consists of 100 houses and is about a mile from the stream on the opposite side at the place where I descended into the valley. On the 4th I followed up the Mártorigár and halted at Rajtoli. There were no villages on the way; Rajtoli consisting of 10 or 12 houses is situated at the junction of two streams which make up the Mártorigár one of them is called the Rajtoligár and the other the Parkhiagár which takes its rise at the Parkhia-lekh hill. On the 15th I followed up the Parkhiagár to its source and crossed the Parkhia-lekh (about 8,095 feet above sea) which is on the boundary between the Bájru zilla on one side and Jumla on the other, and halted for the night at Káláporá village (50 or 60 houses) in the Kunrakhola pattí. On the 6th I followed the Kunrakhola to its junction with the Balarigár about 3 miles from Káláporá about 6,071 feet above sea and crossed the latter, a river which does not take its rise in the snows, but is during the rains too deep, and rapid to be forded. The bridge by which I crossed is wooden and between 40 and 50 feet in length; the depth of the water is about 5 feet. Balarigár below its juction with the Kunrakhola is called by the latter name. The slopes on either side of the stream are cultivated and there are several villages. I kept to the left bank to its junction with the Karnáli river. Here-abouts there are more villages and cultivation on the left bank of the Karnáli than on the right bank. Higher up the river, about 1½ miles above Bánda village I crossed the Karnáli at Jira ghát by a rope bridge about 200 feet in length and 60 feet above water. On the 7th after going north along the river for a short distance I turned up the Khátiarkholagár at its junction with the Karnáli and kept along the stream, crossing and recrossing by small wooden bridges occassionally and halted for the night at a deserted cow shed (Gahu-ka-got). About 2¾ miles above this a small stream, the Kanwakholagár, coming from a S. E. direction joins the Khátiarkhola, my road lay along the former. There is also a road along the latter which comes from a N. E. direction to this junction, leading to Múngú Bhót. I left the Kauwakhola about 2½ miles above the junction and ascended the hill to the village of Kálákhatá (50 or 60 houses) about 1½ miles above the stream, where I remained for the night, it is 12,484 feet above the sea. On the 9th, I crossed the Kálákhatá ridge—very high (about 14,528 feet)—on which the birch and juniper grow and entering a ravine arrived at Lurkon village on the Sinjakhola or Himawati, a river coming from the snows distant about 13 miles, and entering the Tila river. I halted at Lurkon on the 10th. The Sinjakhola pattí is considered the most productive in these parts. Rice is the only crop, raised by means of irrigation. Ponies are bred in great numbers in this pattí. On the 11th, I crossed the Sinjakhola a little less than a mile above the village of Lurkon by a wooden bridge 2 feet wide, 200 feet in length and 15 or 20 feet above water. The current is very rapid and 7 or 8 feet deep. The road then ascends by a ravine a high ridge, (about 13,000 feet) with birch and juniper growing on its summit, which it crosses. On the 12th, I descended into a ravine which joins the Tila river below Chaughan, and along which the road runs, and arrived at Chaughan (Jumla) situated on the banks of the Tila river and about 8,016 feet above sea level. Chaughan consists of a collection of mud houses forming a street occupied by 5 or 6 bunniahs, 2 or 3 cloth merchants from Doti, 40 or 50 priests of the Chandan Náth Mahadeo temple, a few paces to

the east of the street are located the custom house people, 300 sepoys, 3 subhadárs and a captain, Debí Mánsing Basaniath, who is also head man in the Jumla Zillah. To the southwest of the street are the stores of guns, ammunition and provisions within an enclosing wall 600 feet east and west, and 400 feet north and south with a gate to the north, these are also of mud. Chaughan is situated in a plain running north-east and south-west about 3 or 4 miles and about 1½ miles in breadth, surrounded by high mountains about 12,000 feet above the sea. The whole valley is cultivated and there are numbers of villages scattered over it. A road from Taglakhar passes through Chaughan and Dailekh and goes on to Lucknow. Having got a pass and letter of introduction to the Loh Mantang Rájá I left Chaughan (Jumla) on the 18th.

On the 20th I left the Tila river and crossed the ridge to the south by a pass, the Morpáni Lekh, about 12,458 feet above the sea, descended into the Kaikhola valley in the Tibrikot zillah, passed through Bhotia (7 or 8 houses) and halted for the night at a temple between 2 or 3 miles further on and a mile from the Kaikhola river. A road goes from these parts to Lángú Bhot, distant 8 or 10 marches, by the Kaikhola. Next day I crossed the Balangúr Lá pass, lower than the Morpáni Lá, on which oak and rhododendron grow and reached Tibrikot. Tibrikot is situated on the right bank of the river Bheri where it is joined by a small stream from the snows to the north and about 7,226 feet above sea level. To the south of the village about 200 yards, on a hillock about 200 feet high, is a fort (Kot) which encloses a temple and 3 or 4 houses. I was here shown the Civil and Criminal Code of Nepál, which is taken partly from the Shástras and partly from the Indian Code of Civil and Criminal Procedure. It is in the Nepálese language. Having obtained another pass from the Thánadár of this place I left Tibrikot on the 27th.

From Tibrikot I followed the course of the Bheri river and reached Charka on the 4th September having passed some Lámaserais on the road. One of them, called Barphang Gonpa, contains 40 or 50 Lámas. Near another, named Kanigang Gonpa, the river has high perpendicular, rocky banks, and the people have made a tunnel 54 paces in length through the rock. There was originally a crevice and the rock on either side of it was cut away sufficiently to allow of a man with a load to pass through with a squeezing, the height of the tunnel not being sufficient in all parts to admit of his going through standing. Charka is the last village on the river Bheri. On the opposite side of the river is a Gonpa (Lámaserai) to which the first-born male of every family in the village, as is the practice among the Buddhists generally, is dedicated as a Láma. I left Charka on the 5th, and ascended the Digi Lá, about 16,879 feet above sea level, called by Goorkhas Bátali-Pátan, by a gentle incline. On either side of the pass there are snow covered ridges. The pass is broad and there is a cairn on it at the watershed. From Digi Lá I descended to the junction of two streams, one coming from a northerly and the other from a westerly direction, which together take an easterly direction and form the Kingi Chú. On the 7th I reached Kágbeni crossing the Káli Gandak by a wooden bridge. Kágbeni is situated at the junction of a stream coming from Muktináth, with the Káli Gandak, and is about 8,953 feet above sea level. It consists of about 100 houses and is inhabited by Bhots.

From Charka there is also a direct road to Labrang Koja, near Tadum from which after crossing a high snow-covered pass, distant about 20 or 25 miles from Charka, another road branches off to Loh Mantang. Laden sheep, goats and horses are taken over these roads.

From Kágbeni I made a trip to Muktináth, about 11,284 feet above sea, for a day, to see the temple and the country about it. About a hundred feet to east of the temple is a spring with a sulphurous smell which enters a cistern from which the water runs out from 108 spouts, under each of which every devotee passes. The water collecting in a trough below passes out in two streams which flowing to north and south of the temple meet to the west, thus encircling the temple with water. About 6 or 700 feet from the temple, to the south, is a small mound with a little still water at its base, having a sulphurous smell. From a crevice in this mound at the water's edge, rises a flame about a span above the surface. The people of the place told me that the water sometimes increases in quantity sufficiently to flow into the crevice, the flames then disappear for a while and there is a gurgling noise, a report, and the flames burst up and show again. This spot is called Chume Giarsa by the Bhots. To the northwest of the temple, about 350 yards, is a Gonpa with about 30 or 40 resident Lámas. To the east and southeast of Muktináth, about 2 miles, are lofty snowy mountains extending in a northeast and southwest direction from which the stream takes its rise which flows by Muktináth to the north, takes in the temple water and joins the Káli Gandak river at Kágbeni.

On the 9th I returned to Kágbeni, and on the 10th started with my party, following up the river Káli Gandak. About 6 miles from Kágbeni I crossed a small stream coming from Damudarkund, along which the Loh Mantang boundary runs to the east, and from the junction with the Káli Gandak follows up the latter in a northerly direction. I here left the river which above this flows through a very confined valley. To the west about 2 miles is a snowy range. There are forests of cedar below the snows: no other trees are to be found. On the 11th I went to Khamba Sambha village. The road which keeps to the hill side, is broad and there is a great deal of traffic on it.

On the 12th, I went to Changrang village crossing the Chungi Lá pass, about 11,000 feet above the sea, on a spur from the snows. Changrang consists of 30 houses and a fort, the

winter residence of the Loh Mantang Rájá. A road, chiefly used by pilgrims, from Muktináth by Damudarkund, crosses the Káli Gandak by a ford about 2 miles east of this and joins the other from Kágbeni to Loh Mantang here. It can be ridden over on horse back; the ground over which it passes is not rugged nor high, but there is a scarcity of water and no habitations are met with.

On the 13th after a march of 7½ miles, I reached Loh Mantang. Loh Mantang is situated in the centre of a plain, about 11,905 feet above sea level, between two small streams which meet a little before entering the Káli Gandak, distant about 2 miles: the plain is irrigated by channels. Loh Mantang is enclosed by a wall of white earth and small stones, about 6 feet thick and 14 feet high, forming a square with a side of ¼ mile in length, and having an entrance by means of a gate to the east. In the centre is the Rájá's palace consisting of 4 stories, about 40 feet in height, and the only building to be seen from the outside. In the N.E. corner of the enclosure is a Gonpa containing copper gilt figures and 250 Lámas. There are about 60 other houses, two-storied, and about 14 feet in height, forming streets and lanes. Drinking water is brought in by means of a canal, and this overflowing makes the interior slushy; and since there is always an accumulation of filth the smell is very offensive. Since no census is taken I cannot say how many people there are in the place, but they appeared to be numerous.

Besides the permanent residents there are always numbers of traders from Thibet and Nepál, who either exchange their goods here or take them to dispose of at Lhásá or Nepál. The trade in salt and grain does not extend very far north. Trade is chiefly carried on by "Tháklis" a class of traders of mixed origin, who have the privilege of going to Lhásá and they even go to Calcutta for the purchase of goods. The Rájá, who is a Bhot, collects a revenue from all sources of about 10 or 12000Rupees a year, out of which he pays about 2 or 3,000 yearly to Nepál from the land revenue, and 10 per cent of the taxes levied on goods brought from across the northern frontier, to the Lhásá Government.

The Rájá was very much averse to my proceeding further, the orders of Jang Bahadur that no one should cross the frontier being very stringent; however I was determined to proceed at all hazards and succeeded at last in procuring a pass.

I may here mention a custom which prevails in this part of Nepál. On a death occurring the head Láma at the Gonpa is consulted as to the disposal of the corpse. On being informed of the day on which the death occurred he consults his writings, and gives orders according to the directions therein contained. The corpse either must be buried as it died, or be cut up and thrown to the birds, or the arms and legs being cut off and thrown out of the town, to north, south, east and west, the body must be buried, or lastly the body must be burnt in a sitting posture.

Leaving Loh Mantang on the 19th, I crossed the pass Photu Lá on the 20th, the boundary between Debajúng in Lhásá (Thibet) and the Nepál possessions. The pass is about 15,080 feet above the sea. There is a descent of about 250 feet from the pass on to the plain below. I passed thousands of wild horses grazing on the plain; they were in herds of about 100 each, and are not at all shy. On the 21st I encamped at Chumikgiakdong, a sheepfold on the stream which flows to the west of the plain. Leaving my things at Chumikgiakdong, I went to Labrang Koja an encampment, distant 9 miles. The river is here about 250 feet wide and has a very gentle current. It is crossed by boats made of yak's hides which are sewn at the ends and are attached to sticks at the sides; they are kept dry and thus retain their shapes. After 2 or 3 crossings they are drawn on shore to dry. They are propelled by 2 or 4 oars and 2 or 3 men can cross in each. Next morning, the 23rd, I started for Loh Mantang, and crossed the Cháchú Sángpo 2 miles above its junction with the Brahmaputra. This stream is about 3 feet in depth and 60 feet wide, and comes from a snowy ridge about 14 or 16 miles north of Mantang; I forded it and going ¾ mile further on arrived at Tadum.

Tadum consists of 12 houses and a Lámaserai (Gonpa) situated at the foot of spurs coming from the snows to the north. The former are occupied by men whose duty it is to forward property or letters for the Lhásá Government, or such as they may receive orders to forward. For this purpose they have ponies, yaks, goats and sheep, and their beat lies 2 or 3 marches either way. They are not remunerated directly for their trouble, but escape taxes, the head man of each station, "Tarjum", only receiving a small percentage on the taxes. The "Gonpa" only contains 10 or 12 Lámas. The day following my arrival the head man, "Gopa", sent for me and questioned me as to the object of my travels. I told him I was a physician on my way to Lhásá and shewed him my passes. He however refused to allow me to proceed as it would be at the peril of his own life. I was then locked up for the night. Next morning I made an ineffectual attempt to see the Gopa and my messenger returned with a sowár who had orders to see me across the frontier. On the second day after my arrival I began, with great reluctance and under threats of personal violence, my return journey and reached Loh Mantang on the 28th.

I reached Kágbeni on the 1st of October and on the 2nd started south following the course of the Káli Gandak. The road first keeps along the bank of the river for about 7½ miles and then crosses by a wooden bridge 55 feet long and 10 feet above water, depth of water 4 feet, and goes to the village of Marmáli (100 houses) about 3½ miles further on where I remained for the night.

On the 3rd, following the right bank of the river, I passed through the village of Tukja, consisting of about 100 houses, at which there is a custom house and having crossed the river by a wooden bridge about 70 feet long, I recrossed the river to Lidi village where I remained for the night. On advancing from the first crossing of the river about 2 miles, I came opposite a large village situated on the right bank of the river, called Thak, consisting of about 150 houses. Lidi is a small village of 4 or 5 houses; the inhabitants of which are traders and do little in the way of cultivation. On the 4th about ½ a mile from Lidi, I passed another village of the same name, consisting of about 25 houses, and at midday reached Ghás Bhansár where there is a custom house. I stopped at Dan Bansár which also owns a custom house.

On the 5th no villages were met with during the march and the road passed through jungle the whole distance, crossing several small streams running into the Káli Gandak. I passed the night in the jungle.

On the morning of the 6th I crossed the river about 1 mile below the last halting place. 2½ miles further down on the right bank is the Rání Powa Dharmsála (rest house), above which on the hill side and to the west is a large village. A further walk of 1½ miles brought me to the Rangár river, which comes from a westerly direction from the snows and joins the Káli Gandak. I crossed it at the junction by an iron suspension bridge, constructed at the expense of the Rání who built the rest house. The bridge is about 175 feet long, about 15 or 16 feet above the water. The bridge consists of two thick chains to which the roadway of planks is suspended by iron rods, but as these are of equal length the roadway has the same curve as the chains. Nearly 2 miles further, on the same side of the Káli Gandak, is Beni bazar, a village of about 200 houses. There is another village with shops, on the opposite side of the Káli Gandak, called by the same name. There is communication between the two villages by a rope bridge; and a road not fit for horses goes to Pokhra. To the west of the village on the hill side is a copper mine which is worked, and the copper is either sold and taken to Pokhra, or it is converted into vessels in the village, or coined.

On the 7th I crossed the river Maidi by an iron bridge similar to the one over the Rangár, and marched to the village of Báklúng situated in the Báklúng Pattí. It consists of 50 or 60 houses and 15 or 16 shops. There are copper mines on the hill sides. A captain is stationed here to look after the coining of pice at this place and at Beni and the revenues from all sources.

On the 8th I crossed the river Káli Gandak ½ mile to the east of this by boat, the current being so gentle as to admit of it without risk. The river is about 250 feet wide: the water at this time of the year is not clear and fills the channel. I remained the night at the Rájá's residence at Panglang which is 1 mile from the river. I halted on the 9th and on the 10th started, and arrived at Kusamchaor bazar at the junction of the Moti Naddi with the Káli Gandak. This village which gives its name to the Pattí to the north of the Moti and east of the Káli Gandak, consists of about 100 houses scattered over a plain about 2 miles long and about ¾ mile broad. There are copper mines along the hills on the opposite side, but none on this side. Moti Naddi rises in the snows to the northeast and flows in a southwesterly direction, carrying into the Káli Gandak about ⅓ the quantity of water the latter contains above the junction. It is crossed 1½ miles above the junction by an iron suspension bridge 135 feet long and about 12 or 14 feet above the water which is about 7 or 8 feet deep, similar to those over the Rangár and Maidi. A road to Pokhra fit to ride over starts along the left bank of the Moti from the bridge: horses have to ford the river.

On the 11th I passed through a large village, Dámar, well cultivated, containing about 100 houses, on the left bank.

On the 12th I went to Púrthi Ghát on the river's edge about 2,036 feet above sea level. Púrthi Ghát contains about 50 houses and 15 shops and is in the Gúlmi Pattí. To the west of this about 2 miles on the hill side are copper mines which are being worked in 50 places, and it is said there is abundance of the ore along the hills to the right of the Káli Gandak between Báklúng and this. I remained at Púrthi Ghát 14 days with the intention of spending the winter there and then making another start for the north to carry out the orders I received, but changed my mind and determined on going to Dehra, in order to submit what I had succeeded in doing, as my time would thus be employed and I should besides avoid the risk of losing my notes in case of discovery, to which suspicion on the part of the authorities might lead. I left Púrthi Ghát on the 26th and reached Lánthigáon that night. Next day I passed Aslewá Phedi or Aslewá Tár, a village consisting of 25 houses, in the Gúlmi Pattí, situated on a plain and about ¼ mile from the Káli Gandak, crossed the Rúdar at Badiár Ghát, where the river is about 125 feet wide and 5 or 6 feet deep, and staid for the night at Riri bazar, about 1,305 feet above sea level, at the junction of the Riri Khola with the Káli Gandak. Riri bazar contains 50 shops kept by Niwars, a mint where pice are coined, and a custom house. The pice, called Gorakhpuri pice, are forwarded from this for circulation in the Gorakhpur district, where they are current amongst the people though not received at the Government Treasuries. The only copper coin current in Nepál is a mixture of iron and copper made at Katmándu, 48 Katmándu pice go to the Nepál "Mohur" and 2 Mohurs and 2 annas of the Indian coinage go to the Indian Rupee. Two great roads cross here, one coming from Sil-Garhi Dailekh and Salena and going

to Pokhra and Katmándu, and the other from Muktináth and Loh Mantang in the north to Gorakhpur in the south: there are postal arrangements along these high roads, the runners being Brahmins who have this work made over to them in consideration of their caste, no other calls for work being made on them. There are stations along the roads at the distance of 3 kos or 6 British miles.

On the 20th I halted at Tánsen, which is about 4,668 feet above sea level, and gives its name to the Pattí. At Tánsen there is a fort, a gun foundry and manufactory of small arms, 40 or 50 shops and numbers of huts in which the sepoys quartered here live. The fort is a square building about ¼ mile in circumference, the walls are about 12 feet high and made of brick and mortar with an entrance to the north. Inside are two-storied houses of brick and mortar which are used as the Magazine, Court-house and Treasury, and to the west is the residence of General Badri Narsing, Governor of the district, with an exit from the fort by a small door to the west, through which the members of the household go to the temple, about 30 feet from the fort. Formerly 1,100 men used to be stationed here, but now there are 1,600, who are drilled daily by 2 discharged subhadárs of the Indian Native Army: there are no barracks or lines for the men and they are accommodated in huts. Guns as well as small arms are manufactured in a small brick and mortar building to the south of the fort. To the southwest is the parade ground. During winter the place is deserted, the general and troops going to Batoli, distant 15 miles, the other inhabitants also moving to warmer quarters.

On the 14th November I came to Pilhua village, which gives its name to the Pattí and the next night to Ratamati village in the Rámpúr Pattí. The valley here opens out for some distance to the west, and there are numbers of villages of average size on either side of the river; on the hill sides are forests of pipal, sál, bar and other tropical forest trees. On the 15th I followed the course of the Káli Gandak on the right bank, and 2½ miles from Ratamati came upon the roads from Batoli and Deoniagarh which join here, cross the Káli Gandak at Kilri Ghát, and go onward to Katmándu, joining the road from Pokhra to Katmándu at Chorkatiatar near Gorkha Darwar, from which another branches off and following up the Buria Gandak communicates by Nubri with Thibet. I remained for the night at Thalitár. On the 16th, still keeping to the right bank, I arrived at Kúmalgáon or Ghumari, consisting of 25 houses inhabited entirely by Kúmhárs, who besides cultivating the land make baked earthen pots which they dispose of in the surrounding villages. On the 17th I remained for the night at Tárigáon which is distant from the river about 1,000 feet on the slope and about 6 or 700 feet above it. On the 18th I reached Naoakot by a gradual ascent of nearly a mile along the hill side. From Naoakot the road goes to Arkhali village, distant about ¾ mile, containing about 15 houses, and thence to Bishartar village (36 houses) where I remained for the night. The Káli Gandak is about 1 mile distant, and about 7 miles lower down is joined by the united waters of the Tirsuli Gandak and Buria Gandak rivers. The junction is called Deb Ghát and is held in veneration by the Hindoos, a temple being built there. Below the junction, the river is called the Naraini and has a southeasterly direction. On the 19th, I remained the night at the village of Múkundpúr. None of the villages I passed through on the march had any cultivation in their neighbourhood, but were merely summer residences of the people who during the winter months take all their belongings to the plains to the south, where they have their rice fields. My next halting place was Kunjoli. To the west of Kunjoli about 6 miles is Nawalpúr where there is a Thánah with a captain and 25 sepoys whose duty it is to look after the timber floated down the Gandak or Naraini. On the 21st I went to Lináwar village, containing 100 houses, distant 10¼ miles, where I remained for the night. On the 22nd I intended crossing the river at Kúlhúá Ghát 6½ miles lower down, but finding no boatmen I remained at Kúlhúá village for the night and crossed the next morning.

I remained for the night at the junction of the Naraini and a small stream called the Panchperna and Saonmukhi where there is a brick and mortar temple and rest house (Dharmsála) and 4 or 5 huts belonging to the customs officials, I crossed the river by boat next morning the 24th. The river at the place of crossing is about 800 feet, at the ferry on the right are some huts to which the captain and 25 sepoys employed in the floating timber business come during winter. I went on to Gidhagáon distant about 9½ miles in a southwesterly direction. About 3 miles from this in the same direction I came upon Bhojágáon, a frontier village of Nepál, where there is a custom house and passes are shown and luggage examined. A little beyond Bhojágáon I crossed the boundary, and though disappointed at my want of success in Thibet, I felt thankful that I had been able to return to British territory with such information as I had got together.

GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1874-75,

Prepared for submission to the Government of India.

BY

COLONEL J. T. WALKER, R.E., F.R.S., &C.,

SUPERINTENDENT OF THE SURVEY.

Dehra Dun:

PRINTED AT THE OFFICE OF THE SUPERINTENDENT G. T. SURVEY.

M. J. O'CONNOR.

1876.

BOMBAY BRANCH
OF THE
Royal Asiatic Society.
CLASS 2

BAY OF BENGAL
INDEX CHART
TO THE
GREAT TRIGONOMETRICAL SURVEY
OF
INDIA
SHOWING SEVERAL LARGEST BUT WORK OF TRIANGULATION IN SOUTHERN INDIA,
THE MERIDIONAL AND CONSTITUTIONAL CHAINS OF PRINCIPAL TRIANGLES,
THE BASE LINES MEASURED WITH THE DELAY APPARATUS,
THE LINES OF THE SPIRIT LEVELLING OPERATIONS,
THE ASTRONOMICAL PENDULUM & TIDAL STATIONS,
AND THE SECONDARY TRIANGULATION TO FIX THE PENCE OF
THE MINERALS & THE SEDIMENT GUIDES.
Compiled in 2nd October 1872
ASTRONOMY
CEYLON

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THE OPERATIONS OF THE
GREAT TRIGONOMETRICAL SURVEY OF INDIA
IN 1874-75.

The following is a summary of the several operations of the present year, given in the order in which they will be found described in this report.

			Described at pages of the Report.	Described at pages of the Appendix.
I.	*Trigonometrical.*	The Rámnád Longitudinal Series; Parallel 9½°. ...	(5)	3—a
II.	*Trigonometrical.*	The Operations in the Assam Valley. ...	(6)	18—a
III.	*Trigonometrical.*	The Secondary Triangulation in Burmah. ...	(7)	24—a
IV.	*Trigonometrical.*	The Eastern Frontier Series, Burmah. ...	(8)	20—a
V.	*Trigonometrical.*	The Jodhpúr Series; Meridian 72½°. ...	(9)	26—a
VI.	*Topographical.*	The Survey of Kattywar. ...	(10)	28—a
VII.	*Topographical.*	The Survey of Guzerat. ...	(10)	33—a
VIII.	*Topographical.*	The Surveys in Dehra Dún and the Siwaliks. ...	(11)	42—a
IX.	*Topographical.*	Himalayan Surveys in Kumaun and Garhwál. ...	(13)	46—a
X.	*Spirit Leveling.*	In the Madras Presidency. ...	(13)	50—a
XI.	*Tidal.*	Determinations of Mean Sea-level. ...	(14)	51—a
XII.	*Geodetic.*	Electro-telegraphic determinations of Difference of Longitude.	(17)	55—a
XIII.	*Geographical.*	Trans-Himalayan Explorations. ...	(18)	Second appendix
XIV.	*Computing Office.*	Examination, final reduction and publication of the Observations.	(21)	58—a
XV.	*Cartography.*	Preparation and publication of various Charts and Maps.	(24)	69—a

(2.) The operations carried on during the year under review have produced the following out-turn of work;—of Principal Triangulation, with the great theodolites of the Survey, 89 triangles, covering and area of 6,416 square miles, and disposed in chains which, if united, would extend over a direct length of 297 miles, and in connection with which 2 astronomical azimuths of verification have been measured;—of Secondary Triangulation, with smaller theodolites, an area of 4,049 square miles has been closely covered with points for the topographical surveys, and an area of about 6,000 square miles has been operated in *pari passu* with the principal triangulation;—of Topographical Surveying, an area of 2,176 square miles has been completed in the Himalayas, on the scale of one inch to the mile, and areas of 2,141 square miles, on the two-inch scale, and 1,208 square miles on the four-inch scale, in the course of which 2,026 linear miles of boundary and check lines have been traversed;—and of Geographical Explorations, much valuable work has been completed, on the Northern Frontier of Afghanistan, and on the lines from Ládákh to Lhása, and Lhása to Assam.

(3.) The principal triangulation has been executed with the great theodolites, whose azimuthal circles have a diameter of 24 inches, and are read by 5 equidistant microscopes. The average theoretical probable error of the angles, and the average geometrical error, of the triangles—the amount by which the sum of the three observed angles of each triangle differs from 180° + the spheroidal excess—are shown in the table given in the margin. The number of parties employed on the principal triangulation—which was originally fixed at six, but had by last year been reduced to four—has this year been reduced to three, the party employed on the Brahmaputra Meridional Series having been transferred, on the completion of that chain of triangles, to undertake secondary triangulation in Burmah.

Section.	Probable Errors of Observed Angles.		Geometrical Errors of Triangles.		Nature of country operated in.
	Number.	Amount.	Number.	Amount.	
I.	106	±0″·17	42	0″·55	Plains.
II.	56	·25	19	·48	Hills.
V.	84	·16	28	·47	"
Averages,...	...	±0″·18	...	0·51	

(4.) The financial administration of the Department during the present year has been exceedingly difficult and embarrassing. A large increase of expenditure had been occasioned by the introduction of the system of consolidated salaries, which was effected in 1874, under the anticipation that the increase might be met by 'savings in other quarters'; these savings have turned out to be illusive, and a further increase of expenditure has been incurred by the resumption of operations in Burmah, where almost every description of work is very much more expensive than it is in India proper. The orders and instructions for giving effect to the above measures were followed very speedily by orders for large reductions of expenditure; the latter could not be immediately carried out without keeping a large portion of the establishment of officers and surveyors unemployed; they are now to be gradually carried out within the next three years, by the stoppage of promotions, and a reduction of numbers as vacancies occur by death, retirement, or transfer to other Departments.

(5.) I now proceed, as usual, to report on and give an abstract of the operations of the several Survey Parties and Offices. Further details will be found in the Extracts from the Narrative Reports of the Executive Officers given in the first appendix; and a full account of the Trans-Himalayan Explorations will be met with in the second appendix.

NO. I.—TRIGONOMETRICAL.

THE RAMNAD LONGITUDINAL SERIES; PARALLEL 9¼°.

PERSONNEL.

Major B. R. Branfill, Dy. Supdt. 2nd Grade.
Mr. G. Belcham, Surveyor 4th Grade.
" C. D. Potter, Assistant Surveyor 1st Grade.
Mr. E. W. Laseron, Asst. Surveyor 2nd Grade.

(6.) The operations for the revision of the portion of the Great Arc which lies to the south of Bangalore having been completed, as stated in my last Report, the Madras party was deputed to commence the Rámnád Longitudinal Series, which is to trend east-wards from the Great Arc on the parallel of 9¼°, and had been approximately laid out during the previous year.

(7.) Several stations had to be built and the rays between them to be cleared, before the final observations could be commenced; the series had also to be extended along the coast to the Island of Rámesweram, with a view to the proposed connection of the Survey of India with that of Ceylon. Major Branfill himself took in hand the completion of the stations and rays of the first figure, and sent his assistants to build the stations and clear the rays further in advance. He commenced the final observations on the 29th December and completed six stations by the 20th January, when, finding that he was likely to overtake the station-building and ray-clearing operations—which would have brought his own work to a stand still—he left his assistant Mr. Belcham to continue the observations and proceeded in person to direct and accelerate the operations in advance. It was fortunate that he did so, for the belts of dense palmyra forest, intermixed with groves of cocoanut trees, made the selection of stations very difficult indeed. To carry a zigzag traverse in the vicinity of each ray through the forest was possible, but to clear the straight lines between the stations, down to the ground level, as usual, was found to be impracticable; thus to raise the stations to a sufficient elevation to overlook all intermediate obstacles was the only thing to be done, although the palms grew to a considerable height, and the ground was generally flat. By availing himself of sand hillocks, and constructing an ingenious portable braced stand for the theodolite, and lofty scaffolds for the signals, Major Branfill succeeded in overcoming all obstacles, so that by the end of the first week in March the work of station building and line clearing—to the extent of cutting down or lopping the branches of some of the most obnoxious palms—was complete, as far as Rámnád. The observations proceeded without interruption and were brought to a close by the 1st May.

(8.) Major Branfill's, next care was to extend the approximate series from Rámnád to Rámesweram, with a view to the Ceylon connection. After examining the country, he decided, on account of the increasing density of the palm forest and the rapid narrowing of the land, to utilize the islets of the coral reef which lies parallel to the mainland at the distance of 4 or 5 miles; he thus extended the series by a succession of quadrilaterals as far as the land's end. Next season the remaining portion of the triangulation to connect the Survey of India with that of Ceylon—a sketch map of which is given in my last annual report—will, it is to be hoped, be completed; the work however cannot be begun before the end of the month of January, when the violent winds of the north-east monsoon moderate, and open boats—the only craft this Department can afford to entertain—may ply between the islands in the Straits, to supply the signal and observing parties with water and food.

(9.) The out-turn of field work consists of 27 principal stations fixed by 42 triangles, forming 9 polygonal figures (6 quadrilaterals and 3 hexagons) which cover an area of 791 square miles, entirely in the plains, and extend for a direct distance of 90 miles from west to east. A set of star observations for azimuth was also taken, and 35 secondary points were fixed. I have every reason to be satisfied with the vigorous manner in which Major Branfill has carried on his operations, and with his judicious efforts to reduce their cost, by modifying the structure of the stations of observation, so as to utilize the advantages afforded by the timber

of the palmyra trees, as a set off against the serious difficulties presented by the superabundance of these trees, on the ground over which he was operating.

(10.) For some years past Major Branfill has been making a collection of the common place-names met with in Southern India, with their traditional root-meanings and local applications. A list of these will be found in the Appendix to this Report. Similar lists, collected from other parts of India, would doubtless be of much value to the ethnologist and philologer, as well as to the topographer, throwing some light on the language and history of the inhabitants, and even on the physical geography of the country.

NO. II—TRIGONOMETRICAL.

THE OPERATIONS IN THE ASSAM VALLEY.

PERSONNEL.

Lieutenant H. T. Harman, R.E., Officiating Asst. Supdt. 2nd Grade.
Mr. W. O'Sullivan, Sur. 4th Grade.
" J. O. Hughes, Asst. Surveyor 3rd Grade.

(11.) Lieutenant Harman relieved Mr. W. Beverley of the charge of this party at Shillong, in October 1874, under instructions that he would be required to join the Survey Detachment accompanying the Field Force which was to be sent into the Daphla Hills in December. Thus it was a matter of great importance that he should take the field at the earliest date that it would be safe to do so, and mark out work for his European assistants and Native establishment to perform, during his absence with the military expedition. Starting from his Head Quarters at Shillong on the 3rd November, he was able to devote upwards of a month to the preliminary operations of the triangulation in the country between the Civil Stations of Jorhát and Dibrugarh, and to frame instructions regarding the work which was to be carried on in his absence.

(12.) On the 12th December he reached Borpathár, the second encampment of the Field Force, and reported himself to Major Godwin-Austen, of the Topographical Survey Department, who had been selected for the charge of the Survey Party which was attached to the expedition. He accompanied the Feld Force, as Assistant to Major Austen, until the 7th January, when he was deputed to make a reconnoissance of the Ranga Valley and the hill ranges to the east of the tracts occupied by the Force. Starting from the vicinity of North Lakhimpur, he marched for some distance along the course of the Páns river, taking the most direct and best line to the Daphla villages in the Ranga Valley, which line, though crossing the outer hill ranges, is more open and easily traversed than the route along the Ranga river. Even here however no roads or well trodden foot paths were found, the country was overgrown with dense forest and jungle, and the progress made in each day's march was very small. It was known that no food would be obtainable *en route*, and very little at the Daphla villages when they were reached; supplies of food had therefore to be carried with the party, by coolies, and their daily consumption rapidly decreased the general stock provided for all. Thus Lieutenant Harman was obliged to content himself with a guard of only 12 sepoys; and after reaching the Daphla villages he found that even these men were more than he could feed, and that he would either have to return at once with them, *re infectâ*, or to dismiss them and trust himself entirely to the people of the country. He chose the latter alternative, and succeeded in making good friends of the simple mountaineers; and, after completing his survey of their country, he eventually persuaded them to take him back to Lakhimpur by the Ranga Valley route, though at first they stoutly objected to doing so. They represented the track as very difficult, a mere hunting track, not passable for any man with a load, and certainly not for Assamese coolies, whom they appear to regard with great contempt. Lieutenant Harman found that their accounts of

the difficulties of the route were not much exaggerated, as there were places over which even his dog had to be carried; but latterly it appeared that the chief objections on the part of the Daphlas to taking him by this route were caused by apprehensions that they might thereby incur the enmity of their more powerful neighbours, the Abors, and be punished by them for so doing.

(13.) Lieutenant Harman worked right well, and showed much patience and tact in his transactions with the semi-barbarous inhabitants of a country which no European had ever before entered. He underwent much roughing and exposure, and incurred many risks, but these have been repaid by the success which has crowned his exertions. He has drawn up a very interesting account of his own operations and of the country and people, which will be published by the Surveyor General as an appendix to the Daphla Military Expedition Survey Report, by Major Godwin-Austen.

(14.) Lieutenant Harman had expected that his services with the Expedition would not be required for a longer period than six weeks. But it was not until the month of March, after an absence of nearly three months, that he was able to rejoin his own party and resume the trigonometrical operations. He then found that the amount of progress which had been made during his absence was not as great as he had anticipated; several lines had still to be cleared before the observations of the angles could be commenced. He laboured very vigorously to push the work forward, but found the difficulties too great to be surmounted in the short time remaining before the setting in of the rains and the consequent termination of the field season. In many places the forest was very heavy and dense; and worse than all were the occasional patches of jheel-canes "terribly armed with crooked thorns on every surface," through which the native line-cutters, with their wooden sandals and naked legs, could scarcely creep without suffering severely, and it was found impossible to clear the lines more rapidly than at a rate of little more than 100 yards in a day. Thus the rains had commenced before Lieutenant Harman was able to begin final observations at the stations between which the lines were clear; and very soon the country was flooded to such an extent as to become impassable. Lieutenant Harman had therefore no alternative but to quit the field and return with his party to his head quarters, at Shillong; he completed only two triangles, after expending an amount of labour and exertion on his work, which would have sufficed for a long line of triangulation in almost any other part of India; much of what was done will however be of future value, and tend to expedite the operations of the next field season.

NO. III.—TRIGONOMETRICAL.

THE SECONDARY TRIANGULATION IN BURMAH.

(16.) In May 1874, I received an intimation from the Secretary to the Government of India, in the Department of Revenue Agriculture and Commerce, that the want of proper topographical maps had necessitated the suspension of the Geological Survey in Burmah, that isolated town surveys were being carried out; that Marine Surveys of the coast were shortly to be commenced; and that the government wished me to take early steps for the vigorous prosecution of the triangulation in Burmah.

PERSONNEL.

W. Beverley, Esq., Offg. Assistant Superintendent 1st Grade.
Mr. J. W. Mitchell, Surveyor 4th Grade.
Mr. D. J. Collins, Asst. Surveyor 4th Grade.

(17.) Accordingly the party which had recently completed the Brahmaputra Series, as reported last year, was re-organized and transferred to Burma—under the charge of Mr. W. Beverley,—with instructions to carry chains of se-

condary triangles, from the nearest principal sides of the Eastern Frontier Series, in order to fix all large towns, prominent and permanent objects, peaks, &c., for Topographical and Geological Surveys, and the light-houses, &c., along the coast, for the Marine Survey.

(18.) The establishment was formed into two detachments; one was immediately under Mr. Beverley himself; the other was under his senior assistant Mr. Mitchell, who was now transferred from the Eastern Frontier Series, in connection with which, he had, during the previous season, laid out the design of a secondary triangulation to Pegu and Rangoon. This he was now to finish, while Mr. Beverley worked in continuation, in the country to the south of Rangoon.

(19.) Before commencing his own work, Mr. Beverley examined Mr. Mitchell's selections and found that they required to be modified to some extent. He then reconnoitered the country to the south, and laid out a triangulation down to the coast line near the mouth of the Rangoon river. He took observations to fix the positions of Elephant Point Column and Eastern Grove Light, and various points in the town of Rangoon for the Seaport Towns Survey. He then commenced the observations at the stations, north of Rangoon, connecting his stations to the south with the Eastern Frontier Series, but was unable to observe because of the unfavorable condition of the atmosphere. Two more attempts were made subsequently, on the commencement of the rainy season, but both without success; and the same result attended the resumption of the triangulation along the coast towards China Bakir Light.

(20.) Mr. Mitchell spent much time in reconnoitering the ground and laying out the triangulation to the north of Rangoon, and he took observations from seven stations; but owing to very bad weather, frequent attacks of illness, and other causes, he failed to carry out his share of the operations, and thus Mr. Beverley's work still remains unconnected with the principal triangulation, and consequently does not give any but roughly approximate results. It is expected however that the requisite connection will be made early next season, when the atmosphere will probably be clear and favorable for the observations.

NO. IV.—TRIGONOMETRICAL.

THE EASTERN FRONTIER SERIES, BURMAH.

PERSONNEL.

W. C. Rossenrode, Esq., Deputy Superintendent 3rd Grade.
Mr. H. Beverley, Surv. 1st Grade.
„ J. C. Clancey, Assistant Surveyor 3rd Grade.

(21.) In previous years the triangulation of this series had been brought down from Prome to the northern portion of the Shoay-Gheen Districts, the terminal side spanning the Sittang Valley at a distance of about 30 miles above the town which gives its name to the District. During the present year the series has been extended in a south-easterly direction, to within 40 miles of the town of Moulmein, the stations on the eastern flank resting on the hill ranges which separate the British territories from the Shan States tributary to Siam, while those on the west flank are near the coast of the Gulf of Martaban. Stations have also been selected in advance, through the Province of Tennaserim, to a short distance below the town of Amherst.

(22.) In Section V of my last Report I have given a very full account of the great difficulties which are met with in conducting the operations of this Survey in Burmah, in consequence of the dense forest and growth of tropical vegetation which is usually met with everywhere, the sparse population, the reluctance of the Burmese to work for hire, and the practice in which they indulge of firing the grass jungles during the field season, and thus obscuring the atmosphere to an extent which renders all observations to distant points im-

possible. I need not repeat what has been said on this subject, but allusion to it is necessary, because similar difficulties have attended the operations of the present field season. Moreover some of the stations had to be placed on obligatory peaks of the hill ranges, so far away from the nearest human habitations, and so thickly fringed with forest, that no one was known to have ever reached them; the surveyors had to pioneer themselves with their compasses, and to cut their way onwards through the jungle, scaling great rocks and precipices, without any guide to lead them.

(23.) The out-turn of work comprises a quadrilateral, a double polygon and part of a hexagon, covering an area of about 3,150 square miles and advancing the series a direct distance of about 100 miles. Numerous secondary points were fixed both within and external to the principal triangulation. The preliminary operations for future triangulation were carried over a distance of about 100 miles, and have reached the parallel of Kálégouk Island, on which a station-site has been selected. The principal towns wherein points have been fixed are Shoay-Gheen, Pegu, Sittang and Bhiling; a secondary triangulation has been commenced towards the new Civil Station of Paphoon. The out-turn of work would be considered very good in any part of India, under far more favorable conditions for its achievement; under the actual circumstances of the operations it is all the more creditable to Mr. Rossenrode, and to Mr. H. Beverley, by whom the preliminary operations were conducted.

NO. V.—TRIGONOMETRICAL.

THE JODHPUR SERIES; MERIDIAN 72½°.

PERSONNEL.

Captain M. W. Rogers, R.E., Officiating Deputy Superintendent 3rd Grade.
Mr. W. C. Price, Surveyor 4th Grade.
„ C. P. Torrens, Assistant Surveyor 3rd Grade.
Mr. P. F. Prunty, Assistant Surveyor 4th Grade.

(24.) Captain Rogers returned from furlough and relieved Captain Hill of the charge of the party on the 20th November 1874.

(25.) The triangulation was extended northwards, through the Deserts of Jaisalmir and Bikanir. These tracts are apparently so called because, though inhabited by a comparatively large population during the rainy season and the early portion of the cold weather—when there is still a supply of water in the tanks—they are deserted in the hot season, when the tanks are all dry, and drinkable water is in many parts only to be obtained by being sent for to great distances. The water in the wells is usually brackish and unfit for human consumption; thus water for the survey camps had to be brought from distances averaging 10 to 20 miles, throughout the greater portion of the season.

(26.) The out-turn of work has been very good and creditable to Captain Rogers and his assistants. The principal triangulation was advanced 104 miles along the meridian by a series of polygonal figures, consisting of a pentagon, two hexagons and one double polygon, which cover an area of 2172 square miles. An astronomical azimuth of verification was measured at one of the principal stations. The preliminary operations, for the selection of the sites of stations in advance, were carried over a distance of 64 miles, towards the Sutlej Series. The positions of the towns of Bikanir and Pugal, and other points, were fixed by secondary chains of triangles.

NO. VI.—TOPOGRAPHICAL.

THE SURVEY OF KATTYWAR.

(27.) The operations of this topographical survey have been carried on under the executive charge of Captain Pullan, owing to the continued absence of Captain Trotter on duties connected with the Geographical Explorations in Eastern Turkestan and other regions beyond the British Frontier. The year has been uneventful in the history of the survey, but good progress has been made, both in the field work and the mapping.

PERSONNEL.

Captain A. Pullan, S.C., Offg. Deputy Superintendent 3rd Grade.
J. McGill, Esq., Offg. Assistant Superintendent 1st Grade.
Mr. F. Bell, Surveyor 3rd Grade.
" N. C. Gwynne, Sur. 4th Grade.
" W. A. Fielding, Assistant Surveyor 2nd Grade.
Mr. W. Oldham, Asst. Surveyor 3rd Grade.
" G. T. Hall, Ditto 3rd "
" H. Corkery, Ditto 4th "
Visaji Ragonath and 11 Native Surveyors and Apprentices.

(28.) The out-turn of final topographical work, on the scale of 2 inches to the mile, by this party embraces an area of 1749 square miles, comprising parts of Prants Hállár and Machhu Kánthá in Kattywar and a portion of the southern sea-board of Cutch. The area is less than what was covered last year, but this is satisfactorily accounted for by Captain Pullan, in his report. The triangulation executed in advance for the operations of next year covers an area of 2,200 miles, 200 of which are intended for the Survey of the Cutch Coast. In addition to the above, 1,117 linear miles of traversing were executed in order to demarcate the boundaries of Native States, and to check the details of the plane table survey.

(29.) In my Report for 1872-73, para. 47, I stated that when the operations of this survey should reach the shores of the Gulf of Cutch, every effort would be made to connect them with the survey of that Gulf which was made by Lieutenant Taylor, I.N. This has now been done, and the agreement between the two surveys is reported by Captain Pullan to be very satisfactory.

(30.) As regards the mapping, four new sheets, Nos. 32, 33, 34 and 35, have been drawn in such a manner as to be suited either for reproduction on the full scale of 2 inches to the mile, or for reduction by photography to the 1-inch scale.

NO. VII.—TOPOGRAPHICAL.

THE SURVEY OF GUZERAT.

(31.) During the present year Major Haig has been carrying on the system of operation which has been very fully described in Section VIII of my report for last year, whereby all surveys of British lands, which had been previously made in detail for fiscal purposes, by the Bombay Revenue Surveyors, are combined together, supplemented by topography wherever necessary, and mapped on the scale of 4 inches = 1 mile,—while the remaining portions of the British Districts, and the whole of the Native States, are surveyed and mapped on the 2-inch scale, as in Kattywar.

PERSONNEL.

Major C. T. Haig, R.E., Deputy Superintendent 2nd Grade.
Lieut. J. E. Gibbs, R.E., Assistant Superintendent 2nd Grade.
Mr. J. Peyton, Surveyor 1st Grade.
" A. D'Souza, " 1st "
" A. D. L. Christie, " 4th "
" C. H. McAFee, " 4th "
" E. J. Connor, Asst. Sur. 1st "
" J. Hickie, " 2nd "
" G. D. Cusson, " 2nd "
" G. Hall, " 3rd "
" S. Norman, " 4th "
" C. Norman, " 4th "
Gopal Vishnu and 11 Native Surveyors and Apprentices.

REVENUE SURVEYORS.

Mr. T. A. LeMesurier.
7 Native Surveyors.

(32.) An area of 1,375 square miles has been topographically surveyed, of which 983 square miles was on the scale of 4 inches to a mile and 392 square miles on the 2-inch scale. Thus the out-turn of work, as measured by the area completed, is almost exactly double what it was last year, when the operations were of a tentative nature, and the best method of utilizing the Revenue

Survey details had still to be ascertained, by careful trial and investigation.

(33.) In the Dang Forests an area of about 550 square miles was triangulated. A small area in Sheet 79 was also completed with data points, by traversing, and a further area of about 300 square miles of British territory previously triangulated was prepared for survey on the 4-inch scale, by effecting the necessary connection between the fiscal details of the Revenue Survey and the stations, of the triangulation by means of traversing.

(34.) The country topographically surveyed includes portions of the Dholka, Viramgám and Dhandhuka talukas of the Ahmedabad Collectorate and of the Limri, Lakhtar, Wadhwán and Cambay States, all which have now been completely surveyed, and appertain to Sheets 81 and 82 of the general maps; also portions of the Ankleswar taluka of the Broach Collectorate and of the Olpád taluka of the Surat Collectorate, appertaining to Sheet 14.

(35.) The mapping has progressed very satisfactorily. Major Haig has introduced a valuable printed form, called the "Section Register", in which all the different stages through which each map has to pass are tabulated, so that it progresses regularly, and passes from one class of draftsman to another, according as the stages are divided among the different classes.

(36.) An interesting report by Lieutenant Gibbs of the country in the Dangs, in continuation of the one which was published in my report for last year, will be found at page 36—a of the Appendix.

(37.) The Surveyor General has expressed very decided opinions against the desirability of making any use whatever of the Bombay Revenue Survey details; he has represented to the Government that, in his opinion, the Gujerat maps, on the 4-inch scale, in which full use is made of those details, are not as essential for the requirements of the country as maps on half that scale, obtained from more speedily executed surveys, made without reference to the Revenue Survey work; and he has particularly advocated the early procuring of materials for the completion of the sheets of the Indian Atlas, which are engraved on a scale of somewhat less than ½-inch to the mile. A Committee of Survey and Engineer Officers was therefore appointed by the Government of India to report on the subject. The Committee were not able to agree upon any report; no definite conclusion was arrived at with reference to the utilization of the work of Bombay Revenue Surveys for topographical purposes; and irreconcileable differences of opinion existed regarding the relative cost and utility of surveys on the 4-inch and the 2-inch scales. Under the circumstances the Government had adopted a medium course, and directed that the 2-inch scale is to be employed in future, but that the Revenue Survey maps are to be utilized in the operations.

NO. VIII.—TOPOGRAPHICAL.

THE SURVEYS IN DEHRA DÚN AND THE SIWALIKS.

(38.) These surveys are being made conjointly by a portion of the Kumaun and Garhwál Party under Captain Thuillier, and by the survey branch of the Forest Department which has been lately created and placed under Captain Bailey—with a view to executing special surveys for the requirements of forestry—and, while under formation, has been temporarily affiliated to this Survey.

Personnel of the portion of the Kumaun and Garhwál Survey Party employed in the Dún.

Captain H. R. Thuillier, R.E., Offg. Deputy Superintendent 1st Grade.
Lt. St. G. C. Gore, R.E., Offg. Asst. Superintendent 2nd Grade.
Mr. C. J. Neuville, Surveyor 2nd Grade.
Mr. J. Low, Surveyor 3rd Grade.
„ L. J. Pocock, Surv. 4th Grade.
„ H. Todd, Asst. Sur. 1st Grade.
„ T. Kinney, „ „
„ E. P. Wrixon, „ 2nd Grade.
11 Native Surveyors.

(39.) The survey of the non-forest tracts of the Dehra Dún District, by Captain Thuillier and his party, has made good progress during the year, and Captain Thuillier hopes to be able to complete it, as well as the survey of Jaunsár Báwar, in the next field season.

(40.) The field operations were commenced early in October and continued to the end of April. 225 square miles of country were topographically surveyed on the scale of 4-inches to the mile in the Dún. The whole of Jaunsár Báwar was covered with a net-work of triangles, comprising an area of 470 square miles; 398 linear miles of boundary traverses were executed, and 63 miles of check lines were run over the topographical work of the surveyors.

(41.) The country surveyed presents ground of very varied descriptions, from the flat cultivated lands in the vicinity of the River Asan—a tributary of the Jumna, and the main drainage channel of the Western Dún—to the crest of the Mussooree range, which rises to a height of 5,000 feet above the level of the Dún. The low spurs and broken tracts about the foot of the hills gave an infinity of trouble, both in delineating the features of the ground, and in chaining the boundary traverses; in the latter operation very heavy corrections were required for the reduction of hypothenusal to horizontal values.

(42.) Captain Thuillier reports favorably of the progress of his Native Surveyors, who are said to be improving in the art of delineating ground with the plane table; their traversing work was all reduced in the field and found to stand the usual tests in a satisfactory manner. As the survey advances and the Native Surveyors become better trained, the introduction of this cheap agency may be expected to have a very appreciable effect in expediting the completion and reducing the cost of the work.

(43.) The Index Map of the Dehra Dún and Siwalik Survey, which is attached to this report, shows very clearly the extent of work completed and remaining for execution by Captain Thuillier's party. The uncoloured portions of the map represent the forest tracts which have been or are being surveyed by Captain Bailey.

(44.) Captain Bailey's Annual Report has already been submitted to Government through his own Department, together with my review of his operations. It is here therefore unnecessary for me to say more than that the out-turn of topography is about 288 square miles, which has been done on the same scale as the non-forest tracts by Captain Thuillier; the amount of the boundary and interior traversing was 326 miles. The ground operated over was very broken and difficult, more particularly in the interior of the Siwalik Hills, the intricacy and ruggedness of which are probably unsurpassed by hill ranges of the same altitudes in any part of the world.

(45.) The out-turn of topography executed by these two parties may be considered small, as compared with that of other topographical parties working on the standard scale of 1-inch to the mile, in Native States and in Districts where minute delineation of the features of the ground is not required; or even with that of Revenue Survey parties, working on the same scale and with much attention to detail, but in flat and open country, which requires little or no topographical delineation. In Captain Thuillier's operations the average monthly out-turn of topographical area, during the field season, by a party of plane table surveyors, consisting of 1 European and 2 Natives, was 10 square miles; in Captain Bailey's with two more natives in each party, it was 7¾ square miles; in both cases the native surveyors were new hands under training, but the Europeans in the former were, as a rule, older surveyors and better skilled than in the latter. I am satisfied that there was no want of exertion and painstaking in the execution of the operations, and that a larger out-turn could only have been secured by a sacrifice of fidelity and exactness, in the delineation of the ground.

(46). The conjoint survey will form a map in 42 sheets; of these 18 have been completed and deposited in this office, and 15 have been reproduced to full scale and published by photo-zincography.

NO. IX.—TOPOGRAPHICAL.

HIMALAYAN SURVEYS IN KUMAUN AND GARHWAL.

(47.) During the rainy season of 1874, a detachment from Captain Thuillier's Party, under Mr. Ryall, was located at Almora, the nearest point to the scene of the future field operations at which the recess quarters of the party could be established. Before the rains were well over, Mr. Ryall and his assistants had to take the field, in order that they might reach the lofty ground they had to survey, and make the most of the short interval during which the snow line is at its highest and the atmosphere is bright and clear; this occurs between the cessation of the autumnal rains and the setting in of winter weather.

PERSONNEL.

F. C. Ryall, Esq. Officiating Assistant Superintendent 1st Grade.
Mr. C. H. McAFee, Assistant Surveyor 1st Grade.
Mr. E. F. Litchfield, Assistant Surveyor 3rd Grade.
Mr. I. S. Pocock, Assistant Surveyor 4th Grade.
Mr. J. F. McCarthy, Assistant Surveyor 4th Grade.

(48.) Mr. Ryall conducted a series of triangles through a stupendous gorge overhung by the lofty mountains of Chirkhana and Husaling; an undertaking which, he says, required all his skill and nerve. He also supervised the operations of his assistants who were employed in plane tabling on the scale of one inch to the mile. The difficulties this little detachment had to contend with in the lofty region in which they were employed, and which were successfully overcome, are fully detailed in the Appendix and they reflect credit on all cencerned. Captain Thuillier draws particular attention to Mr. I. Pocock's work in the upper part of the Mána Valley, where the average height of the ground surveyed was over 21,000 feet and the maximum height reached was 22,040 feet above sea level.

(49.) The area topographically surveyed comprises 2,176 square miles, and the portion of country triangulated in advance covers 800 square miles. There now remains only about 1,200 square miles in the Mulla Jower, Dharma and Báyáns Valleys to survey, which will complete the unfinished portion of Garhwál. But as the operations in these desolate regions—to which supplies of food and fuel have to be transported from great distances—are necessarily of a somewhat costly nature, their completion has been postponed for the present, and it will not be undertaken until the expenditure can be met by savings in other quarters.

NO. X.

SPIRIT LEVELING OPERATIONS IN THE MADRAS PRESIDENCY.

(50.) Captain McCullagh, on his return from furlough, succeeded to the charge of these operations, *vice* Lieutenant Harman who had been transferred to Assam. He commenced work at the S.W. end of the Bangalore Base, the height of which had been provisionally ascertained by triangulation which rests on a determination of the mean sea-level at Madras, by Colonel De Haviland. He then carried a line of levels, *viâ* Túmkúr, Sira, Hiriyur Tallak and Rámpur, to to Honur H.S. and into Bellary, from which station the work was continued, *viâ* Alúr, Adoni, and Máduwáram to Raichore Railway station, where it was closed on the 3rd April 1875. The operations were carried on in a very satisfactory manner, and the aggregate length of the lines completed is 297 miles.

PERSONNEL.

Captain J. R. McCullagh, R.E., Officiating Assistant Superintendent 1st Grade.
Mr. A. H. Bryson, Assistant Surveyor 3rd Grade.
Two native recorders.

(51.) At Bellary a junction was effected with the line of levels which had been carried from there to the Port of Karwar—on the western coast—by Lieutenant Harman, in the preceding field season. Captain McCullagh's height of

the point of junction is 4·5 feet greater than Lieutenant Harman's; but the discrepancy is believed to be in great measure due to inaccuracies in the determinations of the datum points of the respective lines, both of which are provisional only; final results will not be obtained until the mean sea-level has been exactly determined at Karwar, and probably at Madras also; the difference of level between Madras and Bangalore also needs to be more exactly determined than at present.

NO. XI.—TIDAL OBSERVATIONS.

DETERMINATIONS OF MEAN SEA-LEVEL IN THE GULF OF CUTCH.

PERSONNEL.

Captain Baird, R.E., Offg. Deputy Superintendent 3rd Grade.
Mr. T. Rendell, Asst. Sur. 1st Grade.
Narsing Dass, and other Sub-Surveyors.

(52.) The primary object of these operations is to determine the existing relations between the level of the land and the sea at certain points on the coasts of the Gulf of Cutch, as a first step towards investigating the question whether progressive changes are taking place in the level of the land at the head of the gulf, as has long been supposed to be the case. It is under contemplation to repeat the operations a few years hence, at the same points, with a view to ascertaining the relations which will then obtain between the land and sea; a comparison between the results of the two series of determinations will show whether any sensible variation of level has occurred in the interim.

(53.) The operations were commenced in 1873; their annual progress, and the several instruments employed, have been very fully described in my reports for 1872-73, and 1873-74. I may here however repeat that the tidal stations are three in number, and are situated respectively at Hanstal Point, near the head of the gulf; at Nawanár Point, half way up on the northern coast; and at Okhá Point, on the southern coast and near the entrance to the gulf. At each station a self-registering tide gauge was set up, and it was a part of the programme of the operations that the relative levels of the three stations should be determined by running lines of very carefully executed spirit levels between them. No harbour walls or piers being available, at either place, for the tide gauges to be erected on—over deep water—it was found necessary to set up the instruments on shore, at the nearest points to deep water, and to connect them with the sea by a system of piping, of which the land portion was rigid and the sea portion flexible. The flexible piping terminated in a 'rose', which was suspended from a buoy in deep water, while the rigid piping was conducted to the bottom of an iron cylinder, which was sunk vertically—its lower end being closed by an iron plate—into a masonry well over which the tide gauge was erected. The sea water passed freely through the piping into the cylinder when the tide was rising, and back again when the tide fell, the level of the water in the cylinder being always identical with that of the sea at the same moment, when there was no air in the piping; by means of a stop-cock which was attached to the highest bend of the piping, any air, which might have accumulated internally—as occasionally happened—could be readily expelled whenever the level of the sea rose above that of the stop-cock, which occurred twice daily. The float of the tide gauge rested on the surface of the water in the cylinder, and its rise and fall was duly registered on the barrel of the gauge. Each station was furnished with self-registering instruments for recording the direction and velocity of the wind and the barometric pressure. A native surveyor with a few assistants was placed in charge, and located in a hut in the immediate vicinity of the station. Periodical inspections were made by Captain Baird, and by his assistant Mr. Rendell, and on these occasions the clock errors were determined, the cylinders and pipes cleared of any silt which had been deposited in them, and the instruments thoroughly overhauled.

(54.) Much time was necessarily occupied in the construction of the stations and in getting the instruments into good working order. The regular tidal registrations were commenced, at Okhá in December 1873, at Hanstal in March 1874, and at Nawanár in April 1874. It was hoped that they might be carried on continuously for at least a year, if not longer, at each station, a shorter period being inadequate to furnish the requisite data for an investigation of each of the principal tidal constituents. Considerable anxiety was however felt as to what might happen during the season of the monsoons, when heavy gales are prevalent; but every precaution was taken to strengthen the wooden observatories in which the instruments were set up, and to anticipate and provide for all possible contingencies.

(55.) The monsoon of 1874 set in with great severity and lasted long; but the observatories all stood firm, and the tide gauges and the other self-registering intruments remained in good working order, at all the stations, throughout the season. Unfortunately however at Nawanár the entire configuration of the fore-shore became altered, and an extensive sand spit was formed, below the low water level, on the line of piping, which became completely buried. This occurred in the month of July, and necessitated the suspension of the registrations at Nawanár, until such time as the piping could be extracted and again put into communication with deep water. It was expected that the original configuration of the fore-shore would probably be restored by natural causes, when the wind veered round to its usual direction, which would occur soon after the commencement of the cold weather months; but this expectation was disappointed, and, as the cold season wore on, it became only too certain that the piping which lay beyond the low water line would never be recovered. A supply of new piping was therefore obtained from Bombay and attached by Mr. Rendell to the land portion of the original pipe, and by the commencement of the month of March 1875, after a break of nine months duration, the tide gauge was once more in free communication with the sea, and there appeared to be every probability that it would so remain, at least until the setting in of the next monsoon.

(56.) But the station of Nawanár appears to have been fated to be a trouble and a vexation. Within a fortnight after Mr. Rendell had re-started the tide gauge, he returned, from an inspection of Hanstal station, to see how matters were progressing, and found that during his absence considerable changes had again taken place; the fore-shore had been rapidly shallowing, and the new piping was being fast covered with a deposit of silt and mud, which had nearly reached up to the level of the rose at its outer extremity. He cut it away at once, and substituted several lengths of iron piping, which were held in suspension above the surface of the shore, by being attached—at a level a little below that of the lowest spring tides—to stakes driven vertically into the ground for the purpose. Mr. Rendell remained on the spot for the next two months, taking steps to prevent the rose from being reached by the constantly rising mud and silt; he thus succeeded in getting satisfactory and continuous registrations for the whole of the time, and he checked them by a series of hourly readings taken *pari passu* on a graduated staff, which had been set up in the sea, in deep water, in order to afford a means of verifying the indications of the self-registering gauge.

(57.) At Okhá station all went on most satisfactorily throughout the monsoon of 1874 and the following field season; there were very few breaks of continuity in the registrations, and they were very short and of no importance. At Hanstal the breaks were more numerous and longer; here the water was very muddy, and not pure and clear as at Okhá; consequently there was a tendency for a sediment of mud to be deposited in the cylinder of the gauge and in the piping; this sediment had to be cleared out occasionally and then the registrations were necessarily interrupted; but the breaks in the curves are of no material importance, and they can be filled in by hand from the outlines of the collateral curves, without any risk of significant error.

(58.) The most trying and difficult portion of the operations was the

carrying out of the periodical inspections during the monsoon of 1874. This had proved to be so arduous, and to entail so much exertion and exposure on the officer on whom the duty devolved, that I felt I should not be justified in requesting Captain Baird to carry on the operations through the monsoon of 1875. I therefore directed him to continue the registrations up to within a few days of the commencement of the monsoon, and then to dismantle all the stations, and remove the instruments. These instructions were duly carried out in the month of May.

(59.) Thus the periods during which the tidal heights have been continuously registered at the three stations, are 16½ months at Okhá, 14 months at Hanstal, 2 months at Nawanár in 1874 and 2 months more in 1875. Simultaneous registrations of the direction and velocity of the wind, and of the barometric pressure, were made by the anemograph and the barograph, which were set up at each station.

(60.) The long break in the registrations at Nawanár is to be regretted. But as the station lies nearly midway up the gulf, it is probable that the values of the difference between the mean level for the periods of actual observation and the mean level for the entire year, which are given by the registrations at Okhá and Hanstal, may be safely applied to the results at Nawanár, to obtain the mean level for the year there. Captain Baird has already done this, and obtained very accordant and promising results.

(61.) During the field season of 1874-75, the work of inspecting the observatories, rating the clocks, and maintaining every thing in satisfactory working order, devolved chiefly on Mr. Rendell. Captain Baird was principally employed in conducting spirit leveling operations, for determining the relative levels of the datum points of the three tidal stations, and of the stone bench-marks which had been laid down, a year previously, along the lines to be leveled over. The length of the main lines connecting the three tidal stations was 275 miles, which was leveled over independently by Captain Baird and Narsing Dass, in accordance with the rigorous system of operation which has been followed for several years past in this Department; 29 miles of branch lines were also executed, in order to connect the stations of the Kattywar triangulation with the tidal stations.

(62.) In working between Nawanár and Hanstal, Captain Baird had to make a considerable detour round the head of the gulf, crossing the Runn between Shikarpúr and Malliá. Several bench-marks were fixed on the Runn, and they will be important points of reference when the operations are repeated some years hence. The existing surface level of the Runn has been obtained at a number of points, for Captain Baird took the precaution of having all the pins on which the leveling staves were set up, driven downwards until their heads were exactly flush with the surface of the ground.

(63.) At the close of the field season, the instruments were taken down and the observatories were dismantled. At each station the vertical iron cylinder, in which the float of the gauge had acted, was left *in statu quo*, together with a length of about 50 feet of the iron piping extending sea-wards from the cylinder. The cylinder was filled with clean dry sand, and closed above with a thick planking, after which a massive pile of stones was raised over the ground around it to serve the double object of a protection, and an indication of the position for future reference. The three bench-marks in the immediate vicinity of the cylinder, with each of which the datum of the gauge had been connected, were similarly covered over. Finally the several cairns were placed under the protection of the local officials; and it is to be hoped that the cylinders and bench-marks will be readily discovered whenever the second series of operations are commenced, and that they will be found to have remained undisturbed meanwhile.

(64.) Thus the first series of operations, to determine whether the relations of land and sea are constant or changing, is now an accomplished fact. Great credit is due to Captain Baird for the manner in which he has conducted the task entrusted to him. The difficulties he had to contend with, in obtaining exact re-

gistrations continuously for such long periods, were very serious and formidable; all the stations were situated at points on the coast line which were very far from the nearest habited localities; and the inspections during the season of monsoons, which work was done entirely by himself, necessitated constant travelling during the most inclement time of the year, and entailed an amount of risk and exposure which would tell on a constitution of iron.

(65.) The final reduction of the registrations at each station has been commenced, but it will still take some time to complete. The following preliminary results have however been obtained from the combined tidal and leveling operations—*viz.*, that the mean sea-level is higher, by 7 inches, at the head of the gulf, and by 4 inches, midway up, than it is at the mouth of the gulf.

(66.) During the present year the tidal observations which were taken at the Port of Tuticorin, in the year 1871-72,—with a self-registering tide gauge, similar in all respects to those employed by Captain Baird—have been reduced by the harmonic method, by Mr. Roberts of the Nautical Almanac Office, who has long been employed in reducing tidal observations for the British Association, and whose good services, in aiding Captain Baird in the preparation of his Notes on the Harmonic Analysis of tidal observations, I have already acknowledged in my report for 1872-73. Mathematical expressions have been deduced for each of the several tidal constituents, by means of which the height of the tide, at any moment, may be computed with great exactitude.

NO. XII.—GEODETIC.

ELECTRO-TELEGRAPHIC DETERMINATIONS OF LONGITUDE.

(67.) In consequence of Captain Herschel's absence from this country, on leave to Europe, and of the services of Captain Campbell having been placed at the disposal of Colonel Tennant for an entire year—to assist in the operations connected with the observations of the Transit of Venus at Roorkee—the differential determinations of longitude by the electro-telegraphic method, which were commenced in 1872-73, have been suspended, and the two assistant surveyors and small native establishments employed on them were transferred temporarily to the parties under Major Branfill and Captain McCullagh.

(68.) Captain Campbell's services were replaced at my disposal at the end of April, when the field season of 1874-75 was so nearly ended that it would not have been practicable to resume the electro-telegraphic operations. Captain Campbell came up from Roorkee to Mussooree to frame with me a programme of operations for the following field season, to be undertaken by himself and Captain Heaviside, whose services would be shortly available, for the purpose.

(69.) The first part of the programme was to endeavour, during the approaching season of recess, to ascertain the cause of the imperfect performances of one of the Transit Instruments, while employed in the operations on the line Madras-Bangalore-Mangalore, and to dispense with the induction coils—involving troublesome batteries and frictional electricity—which had hitherto been a constantly recurring source of failure and disappointment in the manipulation of the electric chronographs; *vide* paras 79 and 85 of my report for 1872-73. Both these duties have now been successfully accomplished, as will be seen on reference to Captain Campbell's report in the Appendix. The reduction of a portion of the previous observations—which remained in hand when the party had to be broken up, and has been held in abeyance ever since—has now been completed by Captain Campbell; the final results from the whole of the observations have been found to differ by only ·03 of a second of time, from the preliminary results by a portion of them which have been already published.

NO. XIII.—GEOGRAPHICAL.

YARKAND MISSION. TRANS-HIMALAYAN EXPLORATIONS.

(70.) In my report for last year I stated that, on the return of Sir Douglas Forsyth's Mission to Eastern Turkestan, Captain Trotter—who had been attached to the Mission on my recommendation, in order to utilize any opportunities which might occur for prosecuting geographical investigations—had returned to the Head Quarters of this Survey, and was supervising the reduction of his astronomical observations and the compilation of a map of the country, which were being done for him in this Office.

(71.) The map and his Narrative of the Geographical Operations, with full details of the results, have already been submitted to the Government, and are published in the Official "Report of a Mission to Yárkand in 1873, under the command of Sir T. D. Forsyth, K.C.S.I., C.B.", which was printed at the Foreign Department Press in 1875. It is now therefore only necessary for me to give a brief capitulation of the geographical acquisitions which were the fruits of the labours of himself, and of the Pandits and other natives especially trained for Himalayan Explorations, who were sent to assist him.

1st. The positions of Káshghar, Yárkand, Tashkurghán and Kila Panjah (on the River Oxus, in Wákhán) have been very exactly determined, by astronomical observations; they have been used as the basis of the mapping, and the positions of all other places have been laid down differentially from them.

2nd. The routes from Káshghar to the Chadirkul Lake, on the north, to the Bélowti Pass, on the north-east, and to Marálbáshi, on the east, have been surveyed, the two first by Captain Trotter and the third by Captain Biddulph. The one to the Chadirkul Lake had been previously surveyed by Russian Officers, and it serves as the first connecting link between the British and the Russian Surveys in Central Asia.

3rd. The routes from Káshghar to the south-west, to Badakshán and Kabul, *viâ* Tashkurghán and the Pámir Lands, have been surveyed up to Kila Panjah and to points in Wákhán and near the sources of the River Oxus, some of which had been previously fixed in 1837 by Lieutenant Wood of the Indian Navy, and others by the Native Explorer who is known as the Mirza.

4th. The course of the Panjah Branch of the River Oxus has been surveyed from Wákhán through Shighnán, and down to Kila Wámar and Pigish in Roshán, whereby a considerable portion of the remarkable bend in the river, along the northern border of Badakshán, of which nothing was known previously, has now been clearly defined.

5th. The routes from Yárkand to Khotan, and from Khotan to Kiria and the Sorghák gold fields, on the road to China, and from Kiria southwards, across the Kuen Luen range and the Thibet plateau to the vicinity of Gartokh and Rudokh, have been surveyed.

6th. Various routes between Ladákh and Eastern Turkestan over the Karakoram and the Kuen Luen ranges have been surveyed, some for the first time, though of others we were already in possession of maps of varying degrees of accuracy, which had been constructed by Messrs. Johnson, Hayward and Shaw.

(72.) All these, and more particularly the surveys of the routes over the Pámir Lands and of the course of the Oxus, are very valuable additions to the geography of Eastern Turkestan; and they are especially gratifying to myself as having been obtained, almost entirely, through the instrumentality of an Officer of this Department who was attached to the Yárkand Mission on my recommendation, in order to make the most of the opportunities which would be afforded for surveying these interesting, but hitherto badly mapped, regions.

(73.) On the completion of his map and report, Captain Trotter was about to proceed to Europe, when the Havildar who had been deputed to make a survey of the unknown portions of the course of the River Oxus, and the Pandit who

had been deputed to survey the direct road from Ladákh to Lhása and then to make further explorations, returned to Head Quarters, almost simultaneously, though from such opposite directions. Each of them brought with him numerous journals and records of astronomical observations and route surveys, from which maps had to be constructed and the information extracted and put into a suitable form for publication, as has been done by Major, now Lieut. Colonel, Montgomerie in his reports of the Trans-Himalayan Explorations. Believing that this work could not be performed by any one better than by Captain Trotter, I asked him to postpone his return to Europe, and to undertake it; and he cordially assented to my proposal, though he was thereby disappointed of the gratification of an early return to Europe, which he had been looking forward to. It is to him therefore that I am indebted for the "Report on the Trans-Himalayan Explorations during 1873-74-75", which accompanies this report, and of which I now proceed to give a brief epitome.

(74.) Starting from Kabul, the Havildar struck at once to the north, instead of taking the usual circuitous route to the west, by the Bámian pass. He crossed the Hindú Kúsh range by the Sarolang pass, and, descending to Khinjan, took the direct route by Nárin and Ishkamish to Faizabad in Badakshán, the greater portion of which had never before been surveyed. Thence he proceeded *viâ* Rusták to Koláb, crossing the Oxus at Samti. His instructions were to follow the course of the Oxus upwards, as closely as possible; but he found that this would have led him away from the main lines of communication and rendered him open to suspicion, and that to advance at all into this *terra incognita*, it would be necessary for him to preserve his assumed character of a travelling merchant, and to keep to the most frequented roads. He proceeded in a north-easterly direction, *viâ* Khawáling and Ságri-dasht, to Kila Khumb (the capital of Darwáz) where he again struck the river—here called the Panjah—at the northernmost point of the bend in its course through the mountains, between its rise in the Pámir plateau, and its downward plunge into the plains of Koláb and Badakshán. From Kila Khumb the Havildar advanced for a distance of about 50 miles in a south-easterly direction, along the right bank of the river, making a detour to Kila Wanj *en route*; and finally he reached Yazghúlám, the frontier village of the principality of Darwáz. Most unfortunately he was turned back at this point, under orders from the Khan of Darwáz, who happened at the time to be at enmity with the Khan of Shighnán. Thus his exploration of the river was stopped at a distance of about one long day's journey from Pigish, the lowest point reached by Captain Trotter's native surveyor from the opposite direction. Being ignorant of what this man had already done, and most anxious to complete his survey of the bend of the river, the Havildar eventually returned to Faizabad, and went on to Ishkashim, the well known village on the river, at the eastern end of the bend; he then followed the river downwards, but was again stopped and turned back, this time by the Khan of Shighnán. There is therefore a gap, probably of about 20 miles, between the work of the Havildar from the west, and that of Captain Trotter's agent from the east, which is to be much regretted; but on the other hand it is a matter of congratulation that so large a portion of the course of the Oxus, which was unknown when that river was adopted as the Northern Boundary of Afghanistán, by the British and the Russian Governments, has now become clearly defined.

(75.) Compelled to return from Yazghúlám to Koláb, the Havildar, instead of directly retracing his steps to Faizabad, struck westwards, through regions, on the north bank of the Oxus, of the geography of which very little was known. His route determines the position of the important town of Kabádián, and proves that the Surkháb River—which rises in the Alai plateau to the south of Khokand, and passes through the principality of Karátigin—joins the Oxus, not near Koláb, as has long been supposed, but at a point about 80 miles lower down. His route survey was carried southwards from Kabádián,—crossing the Oxus at the Iwachik ferry—down to the well known town of Khulm, and thence eastwards, *viâ* Kunduz and Talikhán, back to Faizabad.

(76.) While the Havildar's observations were being worked out and mapped in this Office, information was received of the Russian expedition to Hissár, in the summer of 1875. As yet no full accounts or maps, which may have been published by the members of the expedition, have reached this country; but from the "Glance at the Results" by Herr. P. Lerch, which is translated from the *Russische Revue*, and published with notes by Colonel Yule in the Geographical Magazine for November 1875, it appears that Koláb and Kabádián are two of the points which were visited and fixed by the Russian Officers. Thus a second connecting link has been obtained between the British and the Russian surveys in Central Asia.*

(77.) A Mullah, who had been recently trained by the Havildar, was deputed to explore the course of the Kunar River, from its junction with the Kabul River near Jalálabad, to Chitrál, and then on to its source in the Hindú Kúsh range. This man ascended the river as far as Asmár, where he found any further direct advance impossible at the time, because the people of Asmár were at war with the neighbouring Káffir tribes. He therefore made his way over the range of hills on the left bank of the river to Janbatai, a place on the Havildar's route in 1870 from the Punjab to Badakshán, which route the Mullah followed as far as Chitrál. Thence he struck into new ground, ascending the course of the river, *viâ* Mastuj, up to the Baroghil pass; and after crossing the pass he worked up to Sarhadd Wákhán, the position of which had been fixed by Captain Trotter. His work was very carefully executed, and it has shown that the positions for Dir and Chitrál, which were determined by the Havildar, require to be altered by a few miles. It gives the entire course of the Kunar river with the exception of a length of about 25 miles through the Káffir hills immediately above Asmár.

(78.) Pandit Nain Singh—the Pandit *par excellence* of Major Montgomerie's Trans-Himalayan Explorations, whose name it is no longer necessary to suppress as he has recently retired from active employment—was one of the explorers who were attached to Sir Douglas Forsyth's Mission, with a view to being sent into the countries lying either to the north or the south of the Gobi Desert, should an opportunity present itself. As this was not found to be feasible, he was sent, on his return from Yárkand to Leh, on an exploration to Lhása, by a route lying considerably to the north of the one which he had previously taken, and which is described in my report for 1866-67. His instructions were to return to India from Lhása *viâ* China, if possible, otherwise by some hitherto unexplored route through the Bhotan Hills.

(79.) He left Leh in July 1874, and succeeded in crossing the Thibetan frontier, in the disguise of a Láma, or Buddhist priest. Passing about 15 miles to the north of Rudokh, he travelled nearly due east for a distance of more than 800 miles, over a new line of country, separated from the valley of the Tsanpo—or Great River of Thibet—by an almost continuous range of snow mountains, which trends eastwards from the Alang Gángri peaks, in longitude 81°, up to the Ninjin Thangla peaks, south of the great Tengri Nur Lake, in longitude 90½°. His road lay, throughout, over an extensive table land ranging in height from 13,900 to nearly 16,000 feet above the sea level, a region containing a few gold

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* While these pages were being passed through the press I received a copy of the table of "the Latitude, Longitude and Altitude of certain points in Hissár by M. Schwartz, a member of the Scientific Expedition of 1875 to that country", which is published in the Russian Turkestan Gazette No. 49 dated $\frac{9}{21}$ December 1875. The positions it gives for Koláb and Kabádián are very fairly accordant with those deduced from the Havildar's work as will be seen from the following values.

By M. Schwartz							By the Havildar			
Latitude.			*Longitude.*				*Latitude.*		*Longitude.*	
°	′	″	°	′	″		°	′	°	′
37	54	33	69	46	24	Koláb,	37	50	69	48
37	24	23	68	12	15	Kabádián,	37	22	68	11

The longitudes are referred to the meridian of Greenwich.

fields, and numerous lakes and streams, and almost covered with rich pastures; the inhabitants are bands of nomads, who dwell in tents and regulate their movements by the supply of grass and water available for their flocks and herds. The Pandit struck the Tengri Nur Lake at its north-west corner, and travelled along the northern coast of the lake—a distance of nearly 50 miles—to the opposite corner, whence he turned southwards to Lhása.

(80.) He had spent three months at Lhása on the occasion of his first visit, without being discovered to be a British employé. On the present occasion, one of the first men he met was a Muhammadan merchant whose acquaintance he had made at Leh. Fearing that he might be betrayed, he hurried away at once, without waiting for the arrival of a caravan from Leh which was bringing him ample funds for further explorations. It was thus necessary for him to abandon all idea of working his way back through Western China, as his remaining funds would barely suffice to carry him back at once to India.

(81.) The most direct route for him to take was happily one which lay considerably to the east of any that had been previously explored. He followed the Tsanpo (or Brahmaputra) River for a distance of 30 miles, in a portion of its course through Thibet about 50 miles lower down than the lowest which had been reached by previous explorers, and his observations have enabled the course of the river to be laid down approximately for a further distance of about 100 miles, so that the part which still remains unknown is now materially reduced. He crossed the Bhotan Hills by the route from Chetang *viâ* Tawang into Assam, which lies nearly north and south on the meridian of 92°. And finally he brought his work to a close at the town of Odálguri in British territory, and, going down the Brahmaputra river by steamer, reached Calcutta on the 11th March 1875. His astronomical and boiling point observations were very numerous and satisfactory, and his work has been excellent throughout.

(82.) Thus a rich harvest of geographical results—now published in detail for the first time—has been obtained from the labours of the Pandit, the Havildar, and the Mullah; and happily it has been acquired without loss of life or serious misadventure, such as have too frequently been met with in these arduous and hazardous explorations.

NO. XIV.—THE COMPUTING OFFICE.

EXAMINATION, FINAL REDUCTION AND PUBLICATION OF THE OBSERVATIONS.

(83.) Mr. Hennessey—who has for so many years been in charge of this Office, and to whom its present state of efficiency is so greatly due—has been absent on furlough to Europe since the 1st January 1875. The honours have been recently conferred on him of being elected a Fellow of the Royal Society of London, and an M.A., *Honoris causâ*, of the University of Cambridge. During his absence the charge of the Office has devolved on Mr. Cole, by whom its varied and responsible duties have been carried on to my entire satisfaction.

PERSONNEL.

J. B. N. Hennessey, Esq., F.R.S., M.A., &c., Deputy Supdt. 1st Grade.
W. H. Cole, Esq., M.A., F.R.A.S., Offg. Dy. Superintendent 3rd Grade.

Computing Branch.

Mr. W. Todd, Surveyor 2nd Grade.
„ C. Wood, „ 3rd „
„ H. W. Peychers, Surveyor 4th Grade.
Mr. J. Keating, Assistant Surveyor 4th Grade.
Mr. J. Kennedy, Assistant Surveyor 4th Grade.
Baboo Gunga Pershad Computer.
„ Cally Mohun Ghose, „
„ Kally Coomar Chatterjee and 11 other Computers.

Printing Branch.

Mr. M. J. O'Connor, Printer.
19 Compositors and 3 Pressmen.

Photozincographic Branch.

Mr. C. G. Ollenbach, Zincographer.
„ C. Dyson, Photographer.
2 Apprentices, 1 Map Keeper and 3 Pressmen.

Drawing Branch.

Mr. G. W. E. Atkinson, Surveyor 3rd Grade.
5 Draftsmen, 4 Asst. Draftsmen, and 12 Apprentices and map Colorists.

(84.) The Office has been employed in its usual duties of carefully examining and reducing the observations, and publishing the ultimate results of such portions as have been finally treated, and preliminary results of the portions which await the completion of further triangulations before they can be finally disposed of. The 3rd and 4th Volumes of the "*Account of the Operations, &c.*", have been completed and are now in the hands of the binders. They contain full details of the principal triangulation which is contained in the Sectional Figure known as the North-West Quadrilateral, the limits of which are,—on the east, the middle Indian meridian, 78°,—on the south, the western half of the line from Calcutta to Kurrachee,—on the west, the British Frontier line from Kurrachee to Pesháwar,—and on the north, the western half of the Himalayan Range. Of the Synoptical Volumes—which give the results of the principal and secondary triangulation for each series included within these limits, in a condensed form, for the use of geographers and surveyors—three had been published by the date of my last report; in the present year two more, *viz.*, No. 4, the Gurhágarh Meridional Series, and No. 5, the Rahún Meridional Series, have been published: No. 6, containing both the Jogí-Tílá Meridional and the Sutlej River Series, has been completed and is now in the hands of the binders; and No. 7, containing the North-West Himalaya Series and the Kashmir Triangulation has been got ready for the press.

(85.) Another Sectional Figure of the principal triangulation is known as the South-East Quadrilateral; its limits are,—on the north, the eastern half of the line from Calcutta to Kurrachee,—on the west, the central meridian of 78°,—on the south, the eastern half of the line from Vizagapatam to Bombay,—and on the east, the coast line from Calcutta to Vizagapatam. This section I had fixed on to be taken up, for final reduction, on the completion of the North-West Quadrilateral; and it has now been disposed of in a most satisfactory manner, under the supervision of Mr. Cole, to whose interesting report on the subject (in the first appendix), I must invite attention. The third Figure, known as the North-East Quadrilateral, comprises the whole of the country between the one now completed and the eastern half of the Himalayan range (up to the meridian of 89°); its reduction is now in hand.

(86.) Though Volumes III and IV of the *Account of the Operations, &c.*, are now in the book-binders' hands and might be shortly issued to the public, I propose to postpone their publication until the completion of Volume II, which should be issued simultaneously with them. That volume is intended to give an historical account of the triangulation, and descriptions of the methods of procedure and of the instruments which have been employed; to set forth the mathematical formulæ which have been adopted for the several calculations, and to give full details of the final steps in the reduction of the North-West Quadrilateral, when the several chains of triangles are regarded, no longer as separate series, but as a single triangulation, which has to be made consistent *inter se*, and with the four base-lines at its corners. A considerable portion of the volume has been completed and passed through the press, but the part appertaining to the North-West Quadrilateral is still in hand. The preparation of the volume has necessarily fallen in great measure on myself, and it has frequently had to be laid aside, when other matters of more immediate interest required my attention. Of these one of the most important has been the final reduction of the Pendulum Observations, and the preparation of the results for publication. Happening from my long personal as well as official acquaintance with the late Captain Basevi, to be more familiar than any one else with the work he had done, and with his ideas regarding the reduction of his observations, I felt it incumbent on me to set aside Volume II—which is on subjects that are familiar to several of the Officers of this Department, who might complete it in case of mishap to myself—and take up the volume which is to be devoted to the pendulum operations.

(87.) A great mass of experimental observations which Captain Basevi had made—for the determination of the reduction of the given vibration-numbers of the pendulums at the actual temperatures and atmospheric pressures under which the swings were observed, to the corresponding vibration-numbers in a standard temperature and in a vacuum—were still awaiting investigation and discussion at the time of his death; and until this work was completed the final reduction of the observations at the several pendulum stations could not be performed. I took it in hand about the time of Captain Heaviside's return from England, after completing the swings at the stations in the original programme of operations which Captain Basevi did not live to visit. It proved to be a very formidable task; for, excellent as were the experimental observations and great the care which had been bestowed on them, they presented many perplexing anomalies for examination, and these had to be patiently investigated *seriatim*, before any final decision, as to the inferences to be drawn from them, could be formed. All these investigations have now been completed, and the whole of the observations at the several stations visited by Captain Basevi and by Captain Heaviside have been reduced accordingly. A descriptive account of the general operations from first to last, of the several investigations just mentioned, and of the methods adopted in reducing the observations, and full details of the observations themselves—with the results obtained after the reductions—have now been completed and printed for publication; they fill 379 closely printed quarto pages, which will probably form part of Volume V of the *Account of the Operations &c.*, of this Survey.

(88.) It is intended to devote the remainder of the volume to papers by Captains Herschel and Heaviside. Captain Herschel is engaged in investigating the reduction of the pendulum vibration-numbers, from the values deduced for the respective levels of the several stations, to the corresponding values at the sea-level. In previous operations of this nature the reduction to sea-level, which is a question of attraction, has never occupied much time or been of much importance, owing to the fact of the stations having been usually situated at places near and very slightly above the sea. Here on the contrary the selection has, in some cases, been made expressly for the purpose of experiment in the direction of attraction. The stations on the table land of Southern India, and on the skirts of the Himalayas, and more particularly the station of Moré, at an altitude of 15,400 feet in the interior of the Himalayas, are of this kind; and a considerable majority of the stations, on the meridional axis of the Indian continent, are situated at elevations of upwards of 500 feet. There are also several stations which are either at or very little above the sea-level; for one of the objects of the operations was to investigate the relations of sub-oceanic to sub-continental attraction.

Captain J. Herschel, R.E., F.R.S. &c., Deputy Superintendent 2nd Grade.

Captain W. J. Heaviside, R.E., Deputy Superintendent 3rd Grade.

(89.) But enquiries of this nature are far from easy. The calculation of the attraction of a mass of known simple form is often troublesome; but where the mass is a mountainous district, it is absolutely necessary to make a variety of assumptions, of a more or less precarious character, on the legitimacy of which the result must depend. The principal of these has reference to the configuration of the surface. The effective attraction is separable into two parts of which the chief requires an accurate knowledge of the contours immediately round the station; while the other, depending on the curvature of the earth, does not become sensible for some distance, and then continually increases in importance—or more correctly, would do so, but for the general tendency of increased area to present a lower average height,—so that it is hardly too much to say that the effect of distant continents must not be entirely overlooked. Thus a knowledge is required in detail of the masses standing on given areas, and Captain Herschel has necessarily devoted much time to their estimation. The mean height of about 500 half degree squares have thus been obtained for Northern India, Kashmir, Turkestan and Thibet, by a close study of the best available maps. It is probable that the area to be dealt with will have to be extended so as to include a great

part of the Indian continent, should it appear worth the labour. Under the circumstances, there is still much work to be done, before the results of the pendulum operations can be satisfactorily elucidated and prepared for publication.

(90.) On his return from England, Captain Heaviside was employed in this Office, for nearly a year, in completing the reduction of his own observations with the Royal Society's pendulums and in supervising the printing of them and of the greater portion of Captain Basevi's observations. He also completed the reduction of his observations with the Russian pendulums—which had been sent to India to be swung at some of the Royal Society's pendulum stations, with a view to establishing a connection between the operations in India and in Russia—and with Kater's convertible pendulum, which had originally been employed in determining the relations between the length of the seconds' pendulum, and the British Standard Yard, and was re-employed by Captain Heaviside for the conversion of the differential results by the Royal Society's pendulums into absolute values. Full accounts of these operations, and details of the observations and reductions, have been printed in readiness for publication, either in Volume V or in a supplemental volume; they occupy 181 pages of closely printed quarto. The results have been provisionally reduced to the sea-level, but corrections may have to be applied to this portion of the reductions, after the completion of Captain Herschel's investigations. The result of the determination of the present relations of Kater's convertible pendulum to the Standard Yard, which is now being made in the Ordnance Survey Office, Southampton, by Colonel Andrew Clarke, R.E., C.B., is also awaited, to complete the subject, before publication.

(91.) I have every reason to be much obliged to Captain Heaviside for the assistance which he has rendered to myself, and the pains he has taken in completing his own share of the pendulum work. He is now employed with Captain Campbell in the determination of electro-telegraphic longitudes in the Madras and Bombay Presidencies.

NO. XV.—CARTOGRAPHY.

(92.) The preparation of a 3rd Edition of the Map of "Turkestan, and the Countries between the British and the Russian Dominions in Asia," was commenced last year. Each of the four sheets comprising the map had been entirely redrawn, on the same scale as that of the two first editions, *viz.* 1 inch=32 miles, and a large amount of valuable and newly acquired information of Khiva and the regions on the eastern borders of the Caspian Sea—obtained directly from the Topographical branch of the Russian War Office—and of the Northern Frontier of Persia, from British sources, had been inserted. But the completion of the map was postponed until the results of Captain Trotter's surveys, in connection with Sir Douglas Forsyth's Mission, and of the explorations of the Pandit, the Havildar and the Mullah—which I have described in the Geographical Section of this Report—could be introduced into the map. It was then finished and published.

(93.) A new map of Northern Afghanistán, and the Countries to the north of the Trans Indus Frontier—on twice the scale of the Turkestan Map—has been prepared under Captain Trotter's supervision, to indicate the results of the explorations of the Havildar and the Mullah; it is appended to this report. It is exceedingly interesting, its larger scale permitting of much detail being shown which had to be omitted from the Turkestan Map. Two maps, compiled from the Pandit's surveys of the routes from Ladákh to Lhása and thence to Assam, also accompany this report, and contain much new and valuable geography.

(94.) Of other work done in this office I may specify the preparation of Captain Trotter's Preliminary Map of Eastern Turkestan, which has been published with Sir Douglas Forsyth's Report; the completion of the Gazetteer Maps of Kumaun and Garhwál, of 23 Final Charts of the triangulation, in illustration of the Synoptical Volumes, and of 5 Preliminary Charts of triangulation which as yet has not been finally reduced; and the revision of the Map of Routes in Northern India. A tabular statement of the work is given at the end of the first appendix.

(95.) It now only remains for me to acknowledge the valuable services which have been rendered by my Personal Assistant, Mr. H. Duhan, who has relieved me of a considerable amount of official routine work, that would otherwise have taken up much of my time. Mr. L. H. Clarke, has rendered good service by the careful and punctual performance of his duties in the corresponding office and as general store-keeper; and he also acted for three months as Personal Assistant, during Mr. Duhan's absence on leave.

(96.) An abstract of the out-turn of work executed by each of the Survey Parties, whose operations can be exhibited in a tabular form, is given on the following page.

J. T. WALKER, COLONEL, R.E.,

Supdt. Great Trigonometrical Survey.

DEHRA DUN;
Dated 3rd March 1876.

Post-script. 27th March 1876.

Circumstances, which I am not at present in a position to explain, have disappointed me in the expectation of being able to append Captain Trotter's account of the Trans-Himalayan Explorations, during 1873-74-75, to this Report. An account will I trust be published hereafter, and at no very distant date.

J. T. W.

Abstract of the out-turn of work executed by the Great Trigonometrical Survey Parties, during the Official year 1874-75.

Description of Details.	1 Ramnád Longitudinal Series 24-inch Theodolite.	2 Assam Valley Triangulation 12-inch Theodolite.	3 Eastern Frontier Series 24-inch Theodolite.	4 Burmah Secondary Triangulation 12-inch Theodolite.	5 Jodhpúr Meridional Series 24-inch Theodolite.	6 Kattywar Topographical Survey.	7 Guzerat Topographical Survey.	8 Dehra Dún Topographical Survey.	9 Kumaun and Garhwál Survey.	Total.
Number of Principal Stations, newly fixed, ...	27	...	13	...	23	...	...	...	...	63
Number of Principal Triangles, completed, ...	42	...	19	...	28	...	...	...	...	89
Area of Principal Triangulation, in square miles,	791	...	3,153	...	2,472	...	...	...	...	6,416
Lengths of Principal Series, in miles, ...	93	...	100	...	104	...	...	...	...	297
Average Triangular Error, in seconds, ...	0·55	...	0·48	...	0·47	...	...	..	...	...
Average Probable Errors of Angles, in seconds, ±	0·17	...	0·25	...	0·16	...	...	...	...	...
Astronomical Azimuths of verification, ...	1	...	...	...	1	...	...	...	...	2
Number of Secondary Stations whose positions and heights have been fixed, ...	34	..	24	5	12	135?	24	98?	26?	358?
Number of Secondary Stations whose positions only have been fixed, ...	1	...	...	14	...	...	3	...	...	18
Number of Secondary Triangles of which all 3 angles have been observed, ...	10	...	24	11	22	211	35	119	23	455
Length of Secondary Series, in miles, ...	...	...	...	28	55	...	...	...	...	83
Area of Secondary and Minor Triangulation, in square miles, ...	1,096	...	2,249	2,000	681	2,200	559	490	800	10,075
Number of Points fixed by intersection, but not visited, ...	35	30	40	41	14	666?	92	596	56	1,570?
Length of boundary lines and check lines traversed, in miles, ...	...	...	...	...	...	1,117	448	461	...	2,026
Area topographically surveyed on scale of 1 inch = 1 mile, in square miles, ...	...	...	...	...	...	. .	...	...	2,176	2,176
„ topographically surveyed on scale of 2 inches = 1 mile, in square miles, ...	...	..	...	...	...	1,749	392	...	...	2,141
„ topographically surveyed on scale of 4 inches = 1 mile, in square miles, ...	...	...	...	...	...	...	983	225	...	1,208
Number of Revenue Survey Stations and boundary junction pillars, fixed by triangulation, ...	...	...	...	...	1	...	...	22	...	23
Do. of Principal Stations selected in advance, ...	20	...	10	...	7	...	...	...	...	37
Lengths of Approximate Series, Principal, in miles, ...	59	...	100	...	64	...	...	...	...	223
Do. of Approximate Series, Secondary, in miles, ...	...	38	...	94	55	...	...	...	...	187
Number of Towers constructed, ...	5	...	1	...	...	...	...	...	...	6
Do. of Pillars and Platforms constructed for Principal Stations, ...	19	...	13	...	17	...	...	...	...	49
Do. of Pillars constructed for Secondary Stations, ...	...	6	3	7	26	...	...	...	...	42
Do. of miles of Rays cleared, ...	118	106	...	29	15	...	...	...	...	268
Do. do. Path-way made, ...	2½	...	190	5?	1	...	...	...	...	198½?
Do. Hill-tops cleared of forest and jungle,	4	...	28	7	...	...	...	5	...	44
Do. Principal Stations whose elements were computed, ...	27	...	10	...	42	...	...	...	...	79
Do. Secondary and Traverse Stations whose elements were computed, ...	35	...	50	71	101	...	...	6,871	...	7,128
Do. Preliminary Charts of Triangulation, ...	1	...	1	...	1	...	...	...	...	3
Do. Topographical Maps completed, ...	...	...	...	...	...	16	14	7	13	50
Do. Principal Stations placed under official protection, ...	35	...	...	...	17	...	...	...	...	52
Do. Stations protected and closed, ...	12	...	...	...	24	...	...	...	...	36
Do. Points fixed by traverse, ...	...	...	...	...	...	?	1,133	6,005	...	7,138?
Do. Aneroid Determinations of Height, ...	...	...	...	...	...	...	...	236	148	384
Do. Azimuths computed, ...	1	...	...	...	3	...	...	...	...	4

APPENDIX.

EXTRACTS FROM THE NARRATIVE REPORTS

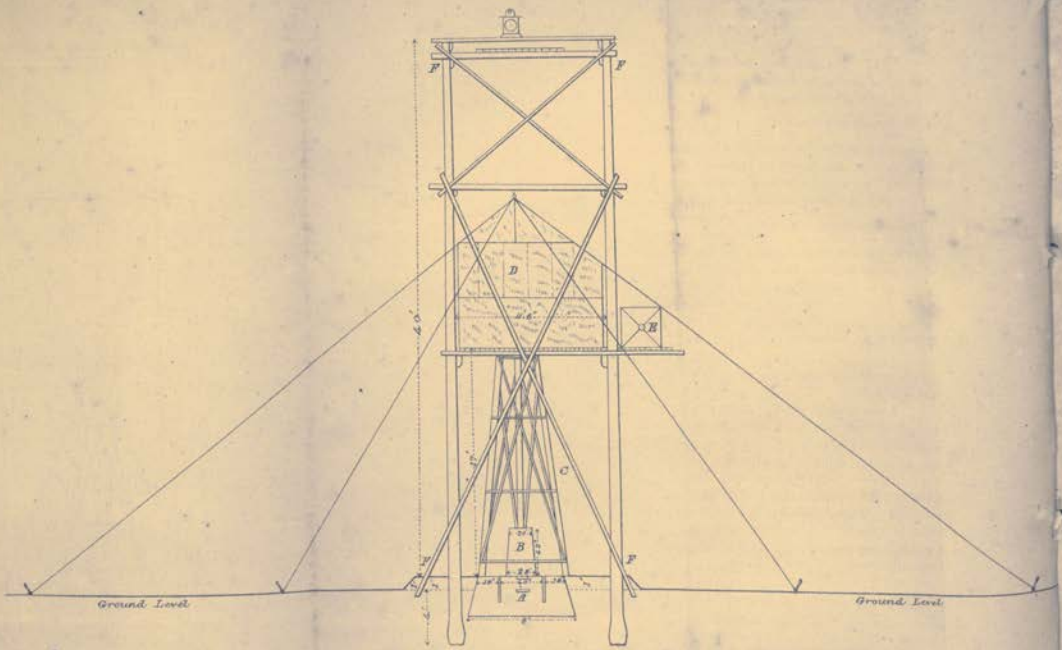
OF THE

EXECUTIVE OFFICERS IN CHARGE

OF THE

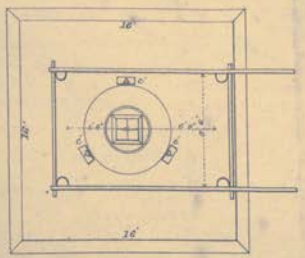
SURVEY PARTIES AND OPERATIONS.

PLAN of a G. T. SURVEY STATION with OBSERVATORY and SIGNAL PLATFORMS shewing BRACED STAND for the GREAT THEODOLITE, designed by MAJOR B. R. BRANFILL, Dupy. Supdt. G. T. Survey, for the RAMNAD LONGITUDINAL and MADRAS COAST SERIES (S. Section).



REFERENCE.

A Masonry pillar and annulus, section and plan.
B Closing pillar in section.
C Wooden braced stand, elevation.
c'c' Masonry support for ditto, in plan.
D Observatory tent,
E Theodolite box, } in elevation and plan.
FF Palmyra platform,



Scale 1 inch = 8 feet.

Photozincographed at the Office of the Superintendent, Great Trigonometrical Survey, Dehra Dún, November 1875.

C. DYSON, PHOTO.

C. G. OLLENBACH, ZINCO.

Extract from the Narrative Report—dated 30th September 1875—of MAJOR B. R. BRANFILL, Deputy Superintendent 2nd Grade, in charge Madras Party.

(2.) The party took the field at Bangalore on the 9th of November, reached Trichinopoly on the 6th of December, Madura on the 12th and the scene of operations on the 20th of the same.

The Season's work to be done.

(3.) The Rámnád Longitudinal Series had been approximately laid out the previous season as stated in my last Annual Report (para. 15). There remained to build most of the stations and clear the rays between them, to select a few of the station sites which had not been precisely determined on, to observe the final angles, and to close and deliver the stations. Besides this the Series had to be extended along the coast to Rámesweram with a view to the Ceylon connection.

Disposition of Party.

(4.) I myself took in hand the completion of the stations and rays of the first figure, a quadrilateral. I sent Mr. Belcham to complete the next figure in advance, also a quadrilateral, and the other two Assistants to build the stations and clear the rays further in advance; one on the northern flank and centre, and the other on the southern flank along the coast.

Final observations after three weeks entrusted to Mr. Belcham.

(5.) I commenced observing on the 29th December at the stations of Kulayanallúr and Kovilpatti, forming a side on the east flank of the Great Arc (Lat. 9°) and completed final observations at the six stations forming the first two figures (quadrilaterals) by the 20th January, when I was joined by Mr. Belcham, whom I had recalled to take up the observations, a mere mechanical process requiring only the skill and care which I felt sure Mr. Belcham possessed and would use.

I was impelled chiefly to take this step in consequence of the great probability of the observing overtaking the approximate series (which eventually it actually did) and because I felt that the most important duty in such difficult country (wooded plains) is the laying out the series in advance to the best advantage, and directing the "Approximate Series" operations generally. I remained instructing and assisting Mr. Belcham for a week, when after seeing him through the observations at two stations I felt confident that I might leave him to pursue the duty successfully.

The Executive Officer in charge proceeds to the front.

(6.) I then proceeded to inspect Mr. Potter's work on the north flank and centre, and, after selecting a station in advance and tracing and clearing the ray to it, visited Mr. Laseron, and gave him a little practical and personal instruction in the art of ray tracing, &c. I next proceeded to build the stations and clear the rays on the south flank, leaving Mr. Laseron to combine his efforts with Mr. Potter in pushing on the building and ray-clearing of the centre and north flank, where the most masonry work was required to be done.

Stations of the north flank and centre, hollow masonry pillars with timber scaffolds.

(7.) The stations of the north flank and centre of the Series were hollow masonry pillars 15 to 25 feet in height, banked up with earth and gravel as high as practicable to prevent vibration, with a timber scaffolding to support the observatory, run up to a much greater height for the signal.

Temporary stations of timber provided on the south flank.

(8.) The south flank lay along the series of sand hillocks and ridges that skirt the coast enveloped for the most part in dense palm forest. The shifting hillocks of drift-sand were not suitable for permanent principal stations, but by their means, temporarily occupied by stations composed of wooden piles, all the permanent buildings on the coast which could be observed, were fixed, and the series rendered a double one throughout. A large mark-stone was buried deeply in the sand, and should the sand hillocks remain, may be found for many years to come. I propose having a pile of (coral) stones placed over each such station more permanently to mark the site in case the sand does shift.

Completion of Approximate Series.

(9.) By the end of the first week in March the Approximate Series on the south flank and centre was complete as far as Rámnád.

Difficulty of the palm forest.

(10.) The south coast of Rámnád, from the lands-end (Toni Turei="*boat ferry*") opposite Pámban, for 50 miles to the westward, is fringed with a belt of dense palmyra forest, intermixed with groves of cocoanut trees, through which it was very difficult indeed to carry on the series, but there was no alternative feasible. To traverse or "*trace*" each ray through the forest was possible, but to "clear" it quite impracticable; to overlook it was the only thing to be done, although the palms grow to a height of 60 feet

and the ground is generally quite flat. At a distance of a mile or so inland from the sea shore there is a ridge or series of hillocks, rising from 10 to 50 feet above their base, formed probably by the constant action of the sea breezes blowing the dry surface sand of the beach inland, and depositing it in the palm forest where it is sheltered from farther action of the wind. After selecting and erecting high flags on the most promising of these sand hillocks for stations, the line between them had to be traversed and the height of the intervening hillocks and of the palms carefully noted. The latter has to be done by climbing the highest palms and examining the height of the forest in the direction of the ray. About midway the most prominent palm in or near the line is sought for and marked with a flag, whence the flags of the two station sites at the ends of the line can be seen; a sextant here may be used to measure the angle contained by the rays to the station flags, which, with the traversed (perambulated) distances gives the approximate position of the true ray, and one is able to judge by examining the top of the forest whether the ray is likely to prove practicable or not, and where most clearing is necessary. Having found the direction of the ray, (and if it still seems practicable) a trial line has to be carried, from one or both ends, *over the palm tops*, the leaves of which have to be cut off leaving a clear gap of 10 or 12 feet in the forest. If the trial line proves all right it has to be widened some scores of trees have to be cut down and their price, (from one to four shillings each), settled and paid to the owners.

Means for raising eye of observer and signals.

(11.) As the sand hillocks do not attain the height of the palms, within 15 or 20 feet probably, the eye and signals have still to be raised, and for this purpose I prepared a portable braced stand of wood 17 feet in height, or else in its place set up palmyra logs steadied by piles of sand, and found they both answered well, and thus the eye of the observer was raised more than 20 feet above the top of the sand hillocks. A much greater height was necessary for the signal, and this was obtained by means of lofty scaffolds, for which as regards length, the palmyra is well suited. The longest, straightest and most convenient trees cut down on the line were selected and split up into halves for the four uprights, and into quarters and eighths for the beams, braces, ties, &c. The stalks of the palmyra leaves furnish the rope by which the scaffold is put together and made fast. Such a scaffold takes two or three days to erect under ordinary circumstances and costs about Rupees 30 (thirty).

The brahmans refuse permission to occupy as a station the Tirupallâni temple tower.

(12.) In one instance I met with a great disappointment and the loss of several days. The lofty gopuram, or entrance-tower, of the Tirupullâni Temple, (a sacred Vishnu fane,) offered a tempting site for a station, eighty (80) feet above the ground, by which five rays to adjacent stations over the palm forest were well commanded. I visited the place and was allowed to mount and observe with a small theodolite from the summit of the tower without demur, and was informed that I might use it as a station, engaging to do no damage that I would not make good. When however I came subsequently to prepare the station, and had been allowed free access a second time, and had taken the necessary measurements, for the platform, &c., the brahmans and others attached to the temple, and a large portion of the inhabitants of the village that profits by the temple funds, turned out to the number of some hundreds, and surrounded my tents in a state of much excitement, protesting against my again entering the tower, unless I was prepared to pay many thousands of rupees for its purification, whilst some of them demanded money for the pollution that had already occurred through my presence. I tried for sometime to conciliate them but without effect: they refused me farther access, locked the door, and kept a watch to prevent by force any attempt on my part to effect an entrance, which of course I did not make, though it was with much reluctance that I felt obliged to abandon so advantageous a site. I afterwards learnt that on the day of my first visit a subscription was made and a sum of one or two rupees collected to enable the priests to perform certain purification ceremonies on account of my visit. On hearing this I sent word to the temple manager that I was ready to pay a rent equal to the amount of any such expiatory sacrifices as they deemed absolutely necessary, for as long as we occupied the tower, but they refused. They added that they had already caused the unhallowed government telegraph wire to be removed from passing too near their holy building to a distance of some hundreds of yards, and that they could not let me use their tower at any price. No anger or ill will was displayed on either side, but I was not prepared for such persistent obstructiveness, considering I had already established a station on the unfinished gopuram at Uttara Koshamangoi, a celebrated Shiva temple only a few miles distant, without any difficulty. The gopuram, or entrance-tower, of any Indian temple is perhaps of less use, from a religious point of view, than the ordinary tower of an old English Church; and in this instance, as is common in Hindu temples, the tower being the sole resort of monkeys and bats, and seldom or never cleaned, was in a most filthy state, and so disgustingly loathsome as to be almost unendurable to any

one passing through it. That my presence should be thought a greater pollution to the temple than that of these unclean beasts and birds, reveals a state of mind that is somewhat remarkable. I lost no time in searching for another point, but the delay caused by the abandonment of this cost me about a week in the busiest time of the season.

(13.) My next care was to extend the series to Rámesweram with a view to the Ceylon connection. After a careful examination of the country to the south-east of Rámnád, I found that the increasing density of the palm forest and the rapid narrowing of the land, obliged me to attempt to utilize the islets of the coral reef which lies parallel to the shore of the main land at the distance of 4 or 5 miles. I accordingly threw out a quadrilateral to the southward based on the last, (south-easternmost) side of the triangulation which lay convenient for the purpose, and found no great difficulty in extending the series by a succession of quadrilaterals as far as the lands-end.

Eastern extension for the Ceylon connection by an island series.

(14.) The islands are scarcely above the sea at high water of spring tides, and are composed of coral and sand and devoid of fresh water or anything to live upon, although they are covered with a coarse grass, weeds and some bushes and trees, the last planted by the fishermen who resort there from the main land: several of them were densely covered with high tangled bushes that caused much trouble to clear a ray through. Labor, material, food and water have to be transported thither by boat, and as constant communication by open boats or canoes must be maintained, there are only about three months, February, March and April, between the monsoons, during which this work can be carried on. The last four stations built and observed at, are of good permanent masonry, as also are two of those in advance, on the island of Rámeswerum, observed to but not yet observed at. High scaffolds were required at all of the island stations, and in building these only one accident occurred throughout, which I think very fortunate, considering that we were all of us inexperienced in this kind of work, and that our materials and implements were of the most unwieldy and roughest description. An ordinary palmyra freshly cut down weighs about 1¼ tons, and each half tree over forty (40) feet in length, probably ½ a ton, to raise which we had a working party of from 12 to 20 common coolies and 3 or 4 klassies. A few stout bamboos for sheers, props, &c., a pair of metal blocks with a stout cotton rope and plenty of "Coir" (cocoanut fibre) rope were all our implements, but they proved sufficient for the purpose.

The islets of the coral reef.

(15.) The one accident alluded to, occurred by a faulty beam, injured in the felling of the tree, having been inadvertently used on the top of the scaffolding to support the signal platform. On noticing this I ordered its removal, but it gave way in the process, and two klassies were precipitated to the ground from a height of about thirty (30) feet; one of them was hurt a good deal, and is scarcely well yet.

Accident.

(16.) I completed these stations and cleared all the rays by the middle of April, when I found it necessary to desist, as it was useless to prepare the remaining stations in advance, some of which must be temporary stations, (being unavoidably on hillocks of drift-sand), unless the final observations could be carried beyond them to two or more permanent stations still farther in advance, and this was quite out of the question. I therefore contented myself with visiting the Islands of Kachi, and Neduvan (or "Delft") and ascertaining that there was no great difficulty in any of the rays in advance, as far as the completion of our share of the series.

Conclusion of the island Approximate Series.

(17.) Mr. Belcham meanwhile pushed on the final observations with vigour and success without interruption, except for one or two days when he overtook the building parties. On reaching Rámnád S. on the 18th March I joined him for the Azimuth observations, and after two days and nights instructions and assistance, found him quite able to complete the work alone, which he did after I left him without any mishap. I am glad to say he continued to work steadily, and made good and uninterrupted progress, until he brought the work to a close by the 1st May, when I ordered him to desist, and to return to quarters, as the entire party was much exhausted, and a large portion of it sick or ailing, officers included.

Progress of the final observations.

(20.) Mr. Belcham has done a good season's work having conducted the final observations with the 24-inch theodolite very creditably to himself, this being his first season, and quite to my satisfaction. The conduct of the observing and signal parties for the island series required much forethought and good arrangement; but he was equal to the occa-

Mr. G. Belcham.

sion, and no mishap or failure occurred to hinder the work throughout.

Mr. C. D. Potter.

(21.) Mr. Potter has worked willingly and well as usual, taking an interest in his work. He has built 7 masonry pillar stations, and traced and cleared 19 miles of rays. He suffered severely in health towards the end of the season.

Mr. E. W. Laseron.

(22.) Mr. Laseron commenced the season's work under the disadvantage of not having had any previous practical experience of ray tracing and clearing in a flat and wooded country, and he found much difficulty in making the "trial lines," laid off from his ray trace observations, come out right, even after repeated trials, and in this way he lost considerable time. He appears however to have worked hard and willingly, and will I do not doubt master the difficulty with a little more practice. He has built 3 high signal scaffolds, traced and cleared 64 miles of rays, and built, partially or entirely, 6 masonry stations. He also built closing pillars at, and delivered over-charge of, 12 principal stations.

General features of the country, soil, &c.

(24.) The country is as flat as possible, although there is a slight slope down towards the sea of a few feet per mile. Inland the country is generally deep black (cotton) soil, which is immediately succeeded near the coast by deep sand. The black soil is extremely rotten, becoming impassable in wet weather and nothing but yawning cracks when dry. The former inland, is much wooded and intersected by tanks, and a net work of bunds, dykes, and supply channels for collecting water, and it is every where cultivated with high growing corn crops, so that the view in all directions is obstructed or confined to a limit of a mile or so even when the observer's eye is raised above the corn which grows up to ten feet in height. Moreover every tank bed (and tanks abound, witness Indian Atlas Sheet No. 80), is overgrown with a dense thicket of thorns of a kind of hard and matted "Bábul" (mimosa Arabica) that is exceedingly tedious to clear a ray through.

Except for the occasional sand hillocks, the vicinity of the coast offers no advantage over the inland tract, in as much as it is overgrown with palm forest, thorn jungle and cocoanut groves.

Bad signals and grazing rays.

(25.) Compared with previous seasons' triangulation, with hill stations, the signals and observations were very wild, as was to have been expected. Excepting the first few, nearly all the rays were unavoidably very low, grazing within 10 or 15 feet of the ground, and a few much closer still.

Factor of Refraction, inland largely negative: over sea positive, but small.

(26.) We have eleven rays more or less clear over the land giving a mean factor of positive refraction = + 0·023 of the contained arc. Thirty-six rays graze more or less badly over the land, giving a mean factor of negative refraction = — 0·111: the largest of these is — 0·289, and there are several others about one fourth of the contained arc.

Of sixteen rays over the sea, some clear and some grazing, only one gives negative refraction, (—0·087,) the rest are all positive, and generally between + 0·020 and +0·040, the mean being + 0·032 of the contained arc, or about half that of an ordinary series of hill stations.

Extension of the Madras Coast Series.

(28.) Besides the plan of the Island Series for the Ceylon connection, one hexagon of the Madras Coast Series to the north of Rámnád was laid out, and three of the stations built by Messrs. Potter and Laseron, and the former has also reconnoitred the country with a view to another hexagon in advance, but nearly all the rays require regular tracing and clearing.

Plan of work for the ensuing season.

(29.) It is much to be regretted that the remaining portion of the Island Series for the Ceylon connection cannot be begun before the end of January when the violent wind of the North-East monsoon moderates, and permits open boats, the only craft our funds admit of, to ply between the islands of Palks Straits to the east of the Pámban channel and Adam's bridge, and keep the signal and observing parties furnished with water and supplies.

I therefore propose employing the strength of the party on the approximate series (Madras Coast) to the north of Rámnád under my own immediate supervision, selecting and building the stations, tracing and clearing the rays between them until enough of the series has been laid out to occupy the observing party until it is time to take up the Island Series, so that as little time as possible may be lost in traversing the interval between the advanced part of the Madras Coast Series, and the uncompleted part of the Ceylon connection.

(30.) I am happy to state that I believe a considerable reduction may be effected by the adoption of only low masonry pillars and platforms, no larger than absolutely necessary for the sake of permanence, in place of the usual high towers. I commenced the Rámnád Longitudinal Series by building high masonry pillars with timber scaffoldings. Ten of these pillars, with a mean height of 21 feet have cost at the rate of Rs. 175 each and the cost of the observatory platform was Rs. 40 making a total of Rs. 215 per station, exclusive of supervision.

Reduction of cost.

Comparative cost of masonry pillars and timber scaffold stations.

(32.) Latterly I have constructed log or pile stations for the sand hills, and low masonry piers for the ordinary soil, with lofty scaffolds for the signals. I find the average cost of eleven observatory signal scaffolds with a mean height of 27 ft. to be only Rs. 30 per station, and I estimate the cost of low masonry platform stations to be about Rs. 20 each, making a total of Rs. 50 per station, showing a saving of Rs. 165 per station. I enclose a plan and elevation of such a station as I have found best adapted for this series and most economical, shewing the portable braced stand with observatory and signal platforms.

(33.) I may notice moreover that the 17 ft. stand has proved more steady in a wind than the 20 ft. pierced masonry pillars previously used.

Stability of 17 ft. braced stand.

(34.) One disadvantage of the lofty signal scaffolds is the difficulty of plumbing the signal apparatus in a wind, particularly in a high wind. This may be obviated by using heavier plummets supported by fine brass wire, and by protecting the plumb line by a long strip of cloth or matting spread on the windward side.

Disadvantage of lofty signal scaffolds.

(38.) Mr. Bond, Assistant Surveyor of No. 2 Extra Party, was placed under my orders for temporary employment in the vicinity of "Bangalore," so as to be ready to join Captain Campbell, R.E., at any time during the season on short notice, in case that officer (who was employed at Roorkee in the observations of the Transit of Venus,) should become available for Latitude observations on the Madras Meridional Series, or other work. I accordingly directed him to execute some minor triangulation in Mysore which was much needed by the fiscal and other surveys, to make a more extended connection of the G. T. Survey principal triangulation with that of Colonel Lambton, and to fill up a gap left in the net work of triangulation of the latter, on the north flank of the Bangalore Longitudinal and between the Great Arc and Mangalore Meridional Series, lying to the south of the "Chitaldroog" district of Mysore.

Mr. J. Bond, No. 2 Extra Party, temporarily attached for special employment near Bangalore.

Ordered to execute some minor triangulation in Mysore.

(39.) He left Bangalore on the 24th November with a party of 12 Klassies most of whom were quite new to the work, and starting from the side Rámadevara-betta —Dodnir-manga H.S. of the Great Arc (in Lat: 13° 30') he proceeded westwards, and in about seven weeks laid out a series of thirteen triangles reaching as far as Shimoga S., about 108 miles in length, and covering an area of 1,096 square miles. Two of these stations are previous G.T.S. points, besides the three initial and terminal stations above named, and four of them are identical with old stations of Colonel Lambton's Survey at which the ⊙ mark was found.

Takes the field and lays out the Series.

(40.) He then commenced to retrace his steps observing the angles, but was very shortly prostrated by sickness and obliged to return to Bangalore for medical treatment. The season was a very unhealthy one generally throughout that part of Mysore and the men of the party suffered considerably from fever, &c., as well as Mr. Bond.

The observations stopped by sickness for seven weeks.

The delay from this cause was more than a month. As soon as permitted by the doctor, Mr. Bond again took the field and the observing was resumed on the 28th of March after an interval of seven weeks during the best season for the observations, and continued till the end of May when he had completed 10 triangles in all.

(41.) But he now discovered that one of the rays of his approximate series which he had accepted without due examination, on the credit of Colonel Lambton's Chart of the triangulation in which this ray is shown (and therefore might well have been supposed practicable) was obstructed, and the observing was therefore brought to an end.

Approximate Series impracticable.

An alternative station was selected but the cloudy weather of the S.W. monsoon had set in, and no farther observations could be obtained. After waiting for three weeks more in the hope of completing the series, I ordered Mr. Bond to return to Bangalore where he arrived on the 24th June, leaving the three triangles connecting his work with its proper base, incomplete. I trust however that he may be able to complete this work shortly before the ensuing field season.

Revised.

Bad weather prevents completion of the Series.

(42.) Mr. Bond appears to have worked energetically and to have done his best. His men were many of them new to the work and insufficiently trained, and he was much delayed for want of good and timely signals, as well as by sickness.

(43.) I beg to append to this Report an alphabetical list of the proper names of the stations and land marks fixed during the season, together with those of the surrounding villages and some of the neighbouring towns, that will appear on the records of this party. The vernacular (Tamil) form of each place-name was obtained on the spot, as well as its etymology or root-meaning.

List of the proper names of the stations and points fixed, &c., given.

I do not suppose that all I have given in the list is correct, but it may be accepted as the current local tradition and usage, and as a near approximation to the approved method of transliteration.

(44.) I apprehend that such information, if faithfully and carefully collected, may prove of much general interest, and of special use towards removing from the face of the English maps and charts of India, the great diversity of rendering and erroneous spelling that have hitherto disfigured them, and I propose to give annually such a list as I have now drawn up of the common and particular place-names met with during the field season.

Root-meanings of the place-names presumed to be of use and interest.

Proper Names of Places and Common Village Names met with on the S. E. Coast of India, chiefly in the Madura District of Madras (Tamil Country).

Agrahâram	From S., a village, street, or quarter of a town, set apart for brahmans.
Alankulam	Vil. pr. n. (?)="*Banyan tank*" fr. álei, the banyan, and kulam, a pond or tank.
Alattúr	Alei, the banyan (tree), and úru, a village or town.
Ammá	Mother, "*mamma*", Lady. Amman-Kovil="*Lady chapel*", a temple or place of worship devoted to one of the female deities or demons.
Anakattu	Eng. "*anicut*"; fr. Tel. addamu, between, across, and kattu (to bind) a bund, dam, embankment; also T. anoi, a dam, dyke, &c.
Anappan	Pr. n. A Canarese caste or tribe found in Madura.
Aneipár Tivu	Anei=elephant, párei=rock; and tivu=island (Madura coast)="*Elephant-rock Island*".
Annapánaikon-patti	Contr. for annapúva-náyakkan, a man's pr. n., and patti, a fold, or small village.
Appanúr	Vil. pr. n. (?) fr. appu, a stake or large peg, a wedge; or fr. appan=father, and úru=town, or large village.
Appá Tivu	"*Abbot's Island*". Appa="papa", a term of respect. This island is also called "Shém mudili" (loc. corr. for *Maulavi*) the name of a Muhammadan saint, whose tomb or shrine is much venerated.
Aramanei	"*King's house*", a palace; fr. arasan, a king, and manei, a house, dwelling.
Areikulam	Written *árei*, an edible water-plant, (marsilea quadrifolia), but stated to mean "*six tanks*", as if fr. T. úru, six, and kulam, a tank, reservoir.
Armugam Kottei	"*Six faced (one's) fort*"; áru=six, and mukham; fr. S., the face; a name of Kartikeiya, the War-god, Subramanya.
Aru	A river. Com. use same as for six; in comp. árr, pronounced. átt: see below.
Asuran	Fr. S., a demon.

Athodei	"*River course*"; fr. áru q. v., and odei, a course (fr. otu=run, drive).
Attánkarai	"*River bank*" or "*River side*"; fr. áru q. v., and karai, a bank, shore.
Atúr	A common village name in S. I., possibly for 'álattúr', q. v.
Aykkudi	"*Shepherd's abode*"; fr. áyan, a shepherd, pastor; and kudi, a habitation, dwelling.

B is not a letter of the Tamil Alphabet, but p is sounded like it sometimes, as after m and n, and, with h, is used instead of it in foreign words, and also for p'h, and b'h.

Chadayan	(?) Pr. n. of a caste or tribe in S. I., erroneous for kadeiyan.
Chakkili Medu	"*Currier's mound*"; fr. chakkiliyan, a currier; and medu, a hillock.
Chakrákottei	From chakrá, S., the discus, Vishnu's weapon (a quoit) and kottei, a fort.
Chattram	Vulg. use for chattiram, a native rest-house. Hindí.=chhattar.
Chávadi	The Anglo-Indian "*choultry*" of old writers, a native rest-house for travellers.
Cheri	An assemblage, a hamlet, a small village; allied to C. keri, a street, row, cf. H. kherá, Ar. and H. karya, a hamlet or small village.
Chinni appa Dargah	(?) "*Papa Chini's Dargah*" (Muhammadan shrine), a pr. n.
Chippi-kulam	"*Shell tank.*"; fr. T. chippi, a little shell.
*Daghopa and Dahgop	S., fr. deh, the body, and gup, to hide; a Buddhist altar, vimána or shrine (see foot note).
Dalaváy-puram	Dalaváy, the minister, or commander-in-chief, in S. I., and puram, a town.
Devipattanam	"*Devi's town*" S., Devi=goddess, a name of Párvati, Shivá's consort, and pattanam, a town, a seaport (?).
Dhanu-kodi	"*Bows point*"; fr. S. dhanus, a bow, and kodi, a point. The extreme S.E. point of Rámesweram Island, a sacred bathing place.

In vulgar colloquial use y is commonly prefixed to e initial.

Endal or Yenthal	A small tank; a com. affix to names of small villages in Madura.
Eri	A large street of water, lake, a big tank.
Etteyápuram	Pr. n., a town and zemindári (estate) of the Ettappan (a Náyakkan) family of Tinnevelly.

G only represented in Tamil by k which is pronounced as k when initial, or double, but like g when medial.

Gandha mána-parvatam	Pr. n. of the highest point of Rámesweram Island. S., parvata=a hill.
Giri	S. A mountain in S. I.; com. applied to a hill named in Hindu mythology or history.
Gopala pattanam	"*Cowherd's town* (or port)"; fr. S. gopál, a cowherd, and pattanam or pattinam, q. v.
Idam-bádal	Perhaps fr. idam, left, as there is a "Valam (=right)-bádal" across the fen close by. Idam also means a place. If for Itham-bádal="*Sweet songs*".
Idoiyan	A man of the herdsman caste, or tribe; (?) fr. idei=middle=middle-born, i. e., from Iswara's breast.
Ilampunam	Corrupt. for Ilama-nattam. Nattam is the village-site, or building ground.
Iswara	S. The deity, Supreme God, Lord. In S. I. used for Shivá. "Issuran-koil"="*Shivá's Temple*".
Kachi Tivu	"*Shingle Island*"; fr. Kachchi, a broken shell or sherd; this island is formed of broken coral.

* NOTE.—Pagoda (formerly pronounced pá-god) may be derived from this by metathesis pa-go-da=(da-go-pa, Dr. Sargent). It may be from Pey-gudo Tel. (=Tam. Pey-kovil)="Demon's, or devil's temple," or house.

Kadaládi	"*Sea bather*"; fr. kadal, the sea, and adi, a player, bather; (fr. a local tradition).
Kadaleiyúr	Corrupt, fr. kadasi=last, final; ellei, a boundary, limit; and úru.
Kádamangalam	Perhaps fr. kadu, a jungle, and mangalam=prosperity, fortune. A flourishing village.
Kadavu-Santei, or Kathavu-Chantheí	"*door, or gateway fair*"; fr. kathavu, a door.
Kadeiyákkulam	"*End tank*"; fr. kadei=end, (market). The root-meaning is last (born)=low caste. The Kadayar are below the Kallar.
Kadeiyúr (kulam)	"*Kadeiyan's (tank)*"; a caste or tribe of fishermen (mostly Christians now) about Rámesweram.
Kádu	A barren place, jungle; an untilled or un-irrigated field.
Kal, Kallu	A stone, rock.
Kál	The leg; a quarter, (cf. H. páon, and páo) a stake, stem, prop, pole, shaft, &c.
Kalak kudi	Fr. kalam, a threshing floor, barn. Open field (see Kalari).
Kalari	Barren or brackish ground, a threshing floor="*arena*".
Kaliman gundu	"*Clay-mound*", kaliman, clay, and kundu, a lump, boulder, heap.
Kallan	One of an indigenous tribe, addicted to thieving. Plur. kallar, the "colleries" of Orme's history and others.
Kammai, for Kanmáy	Com. use in Madura for an irrigation tank or reservoir, a common village name.
Kamma-patti	"*Tank fold*"; fr. kanmáy, a tank for irrigation, and patti, q. v.
Kammaya-naiken-patti	Pr. n.="*Kammaya Naik's fold*". Patti, a cattle fold, hence, a small village.
Kánjarangudi	Pr. n. (?) fr. kanjiram="Strychnos nux vomica", and kudi, a habitation, dwelling.
Kappal-madoi	An anchorage; fr. kappal a vessel, a ship, and madoi (?) allied to madu, a pool, a place in the sea deep enough to anchor in.
Káppiliyan	One of a Canarese agricultural caste or tribe in Madura, with com. agnomen "Gaundan" (T. *kavandan*).
Karoi	A border, shore, bank. Common affix to village names.
Karisal-puli	Karisal=black soil, blackness, or any thing black, and puli=tiger.
Karshá-Kulam	Vulg. (?) for Karisara, for karisal, q. v., and kulam, a tank.
Kasavangundu	(?) for kusavan, or vulg. koshavan, a potter, and gundu, a boulder, rock:="*Potter's mount*".
Katari (or kithari)-Amman Tivu	Kithari, corrupt. for Catharine="*Lady Catharine's Isle*", so called from an old R. C. Shrine there.
Kidáthirukoi	Kidá (?) short for Tadáthagei, n. of Minákshi; tiru, holy, and koi, the hand.
Kílakarei	"*East-shore*", v. sup.; about the largest seaport town between Tuticorin and Pámban.
Kíla-kidáram	"*East Kidáram*" (?) kidáram=a bowl, copper boiler, &c.
Kílo	In comp.=eastern; fr. kíle, below, because the country falls to the eastward.
Kodi-kánal	"*Creeper wood*"="*Rattan (cane) forest.*" The first English settlement on the Palney hills.
Kodi-medu	"*Flag-mount*"; fr. kodi, a flag, streamer, a creeper, &c., and medu, a mound.
Kodumudi	"*Flag (staff) point*"; fr. kodi, a flag, v. sup., and mudi, a crown, crest, topknot.
Kokkádi	(?) "*Cranes play*"; fr. kokku, a crane, and ádi=player.
Komba-úthi	"*Horn blast*" or "*Horn blower*"; fr. kombu, a horn, and úthu, blowing.
Koneri	"*King's lake*"; fr. kon=king, and eri, a lake, a large sheet of water.
Kottan Kulam	The old name of this place is Kunthi-nagaram, once a place of pilgrimage.
Kottei	A fort. Com. affix to pr. names of fortified villages.
Kovil or Koil	A (Hindu) temple or place of worship (?) fr. ko=king, pastor, and il, a house.

Kovil Kulam	"*Temple-pond*"="*Church-lake*."
Kovil-patti	"*Church fold*"; fr. kóvil, a temple, and patti, a cattle fold, a small village.
Kúdal-i	A junction. Com. term for the confluence of rivers.
Kudi	A house, dwelling.
Kudisei	A small dwelling=huts, cottages.
Kudi-irupu or Kudiyiruppu	A dwelling, residence; com. n. for a small hamlet in S. I., especially near the coast.
Kudirei-katti-mundal	"*Horse-bound-point*", local name for the Periapattanam headland; fr. kuthirei, a horse, and kattu, to bind. It is said a horse sacrifice was made here.
Kulam	A pond, tank, reservoir of water; usually for irrigation.
Kulaya-nallúr	Pr. kula-Sekhara-n.="*Race head-ornament*"; fr. the n. of an early Pándyan king; and nallaúru="*good-town*"="*fair-ville*".
Kumára-kurichi	Fr. a pr. n. of Subramanya, Kumáran=son (of Shivá), and kurichi =a settlement, village.
Kundu-kál	(?) "*Squatting point*"; kunthu=setting (on), kál, the leg, (?) going on tiptoe. The W.S.W. point of Rámesweram Island, fr. a legend about Hanumán.
Kunru	Pronounced kundru (and in Mal. kunnu), a hill, a small hill, a round stone, a boulder rock.
Kurichi or Kurichchi	A settlement. Com. n. for a small village or hamlet in S. I. properly on a hill, for kundrachi (?).
Kurtálam	(Vulg. "*Courtallum*")=(?) "*Stunted Banyans*" (? fr. kuttru, ? dwarf) and álei, the banyan.
Kurusadi	"*Cross-foot*"; an island nr. Pámban; so called fr. a R. C. Shrine, (kurukke=a cross) and adi, the foot.
Kuruvi-nattam	Fr. kuruvi, a bird, a small bird, and nattam, a village site, a village.
Kuttam	A tank, a large pond.
Kúttam	A collection, assemblage, a crowded group, cluster, &c.; applied to a collection of huts, a hamlet.
Kuttei	A small tank.
Kúvar-kuttam or Kúvat-kuttam	(?) "*Noise-tank*"; fr. kúval=cooing, a crowing noise, and (?) kuttam, q. v., applied to a little village of a few inhabitants.
Latchmi	Fr. S. Lakshmi, pr. n. of Vishnu's consort, or Sakti, goddess of wealth, fortune.
Letchmi-puram	"*Lakshmi's town*".
Lingam	The sacred phallic emblem, symbol of Shivá under which he is worshipped by Saivas.
Madam	Fr. S. and H., math, a school or college for brahmans, a cloister, monastery.
Madura	Town and district or collectorate: derivn. doubtful; perhaps more prly. spelt Madhura (Nelson).
Malei	A hill, mountain, com. use; hence Malabar for Malei-war, and Maleiyálam, the Malabar language.
Malei	Rain. Hence Malenádu, the Maluád or rainy district of Mysore.
Maleipatti	"*Hill-fold*"; very com. n. for vil. at foot of, or near a hill.
Maleswerapuram	Pr. n. (?)="*Hill-gods-town*".
Man	Earth, soil.
Manal	Sand.
Manapád (?)	"*Sand-hill*"; pr. n. of a headland on the Tinnevelly coast between Trichendúr and Cape Comorin.
Manaar	Vulg. use for Mannár=a town, settlement, fixed abode, fr. mannu to be fixed, lasting, to remain; or (?) fr. manuár=enemies, foes.
Mandalam	Fr. S., a region, circle, district, (cf. L. mundus, the world) "Coromandel" (?) for cholamandal, cf. tondamandalam, also= a small temple or shrine.
Mandala-mánikam	Pr. n.="*Region of gems*", or rubies. Mánikkam (fr. S. mani, a gem), a precious stone, gem, a ruby.

Mandapam	A covered court or hall, built with pillars, a rectangular open-sided hall, before or near a temple.
Manditop	Pr. n.; fr. mandi=a monkey, and toppu, a grove, a "*tope*".
Mangalam	Matrimony, praise, delight; com. affix to pr. ns. of wealthy villages of brahmans, rich in rice fields=a flourishing village.
Mannáli	Pr. n. of an island, perhaps fr. its being composed of manal=sand.
Mantri	A chief counsellor, prime minister; a com. prefix.
Marakkayar-pattanam	"*Skippers' town (or port)*"; fr. marakkalam, a ship, (mara, wood, and kalam, a vessel), marakkaya=ship-owner.
Máriyúr	Once a large seaport town on the Gulf of Manár.
Maravan, pl. Maravar	Pr. n. of a tribe of the inhabitants of Madura, of lawless and predatory habits.
Máyákulam	"*Everlasting-pond*"; fr. máy-á, that vanishes not, and kulam, a pond, tank.
Medu (see Motu)	A height, &c., comly. pronounced more as if written modu, moedu, or mōru; e. g., Nagari Mor, a hill near Madras.
Mela-kal-úruni	Pr. n.="*upper (i.e. western)—kal-úruni*", (perhaps stone tank); fr. úruni, a common village tank.
Mela-madai	"*Upper (i.e. west)—sluice*"; fr. madai, a small water-sluice for irrigation, &c. The land first watered being nearest to the sluice is called Mel-madai, and the lowest or last watered land is called Kíl-madai.
Mele	In comp. mel=up, upon, (upper), hence western, west; because the country rises to the west.
Melmánthai	"*West mánthai*" (?) for manthai, mandai or mantai=a herd, flock, (?) assembly.
Motu or Medu	A height, hillock, rising ground, com. use for a swell of high land.
Mínáchi, also in T. Minátchi	For S. Mínákshi="*Fish-eyed*"; a name of Párvati, consort of Shivá=káli.
Mínaugudi	(?) "*Fish-village*".
Mottúruni	Pr. n.; fr. mottai, bald headed, bare, (?) from being on an open bare plain, devoid of trees, &c.
Mudaliyár or Mudali	A title of respect, in com. use in Madras, applied to a Tamil caste.
Mudukulattúr	"*Old-tank-town*"; fr. muthu, ancient, kulam, a tank, and úru, a town.
Múkkoiyúr	Pr. n.="*Cape-town*" or "*Bill town*"; fr. múkku, the nose, bill, beak; (?) so named fr. being near a headland.
Mulli Tivu	"*Conch (shell)—Island*"; fr. mulli, a shankh, or conch shell, once abundant here.
Mundel or Munthal	A headland, cape, point, loc. use for munai, a headland, promontory.
Murugai-talai	Fr. murugai, coarse coral rock, and (?) talai, the head: a common affix, cf. leather*head*, gates*head*, &c.
Musal Tivu	"*Hare-Island*"; fr. musal or muyal, a hare. Hares are still found on Hare-Island at Tuticorin.
Muttupettai	"*Pearl-town*"; fr. muttu, a pearl (cf. H. moti), and pettai, a (market) town, a village with shops, a bazaar.
Muttúruni	"*Muttu's úruni*" (i.e. tank). Muttu, perhaps the name of the man who had the tank made. A common proper name fr. muttu, a pearl.
Nádu	A district, country, as opposed to town. In Madura comly. applied to Kalla tracts, (see kallan). The opposite of Kádu jungle.
Naduvupatti	"*Middle-fold*"; fr. nadu, middle, and patti, a fold or small village.
Naiken	Short for Náyakkan, a title borne by men of Telugu (or Telinga) race, a chief, leader.
Nája-mundel	Pr. n. (?) and mundel (q. v.) a headland.
Nallatanni Tivu	"*Sweetwater island*"; fr. nalla, good, and tannír, water (properly tanníru=cool water).

Nallúr	"*Good-ville*"; fr. nalla, good, fair, and úru, a town.
Naripeiyúr	(?) "*Fox-bag-ville*"; fr. nari, a fox, pei (or pai), a bag, and úru, a town or village.
Nattam	The village site, ground reserved for building on. Com. village name in S. I.
Náyakkan	Fr. S. náya, a leader=náya, guiding. In S. I. a title of warlike Telingas, (the "Poligars")=chief, leader; allied to náyar, the honoured Sudras of Malabar.
Neduvan Tivu	On old maps "*Nedóen*", locly. pronounced Nedum="*Long island*".
Negapatam	Vulg. for Nága-pattanam. Nága, snake, "*dragon*", and pattanam, a town, (?) a seaport town.
Nellúr	"*Rice town*", fr. nel, raw rice, "paddy", and úru, a town.
Nerinji-nattam	"*Thistleham*" or "*thornville*"; fr. nerunjil (vulg. "*nerinchi*"), a weed bearing a thorny seed: (tribulus terrestris).
Nerinji-patti	"*Thistlefold.*" See above.
Nochchúruni	Fr. nochchi, a medicinal tree (vitex negundo), and úruni = a tank or well.

In Tamil w is vulgarly prefixed in pronouncing words beginning with o.

Oppilán	Pr. n.=(?) "*the incomparable*"; fr. oppu=likeness, comparison, and illádavan=one destitute of,="*he who is without*". (?)
Ottangudi	(?) "*Builders' village*"; fr. ottan, a well digger, or builder (a caste), and kudi, a dwelling.
Ottapidáram or Otta-pandáram	Fr. a man's name, and a corruption. of "(Alagiya)-pándiya-puram", the ancient name.

P. in Tamil is pronounced like b sometimes, as after m and n, and stands for the labials (Surd and Sonant alike) p, p'h, b, and b'h.

Pád	Tel. a hill, (?) corruption of H. pahár, a hill.
Pádi	A village or town, (in comp. bádi) a row; com. affix to vil. pr. n. (?) a bar (in the sea).
Pádu	A place, situation, location, besides many other meanings.
Pákkam	Com. affix to vil. names near Madras; (?) allied to pakkam T., a side, vicinity, or (?) to bágam, a division, share.
Palaya	Old. Cf. Gr. palaios, old.
Páleiyam	A place or district under feudal tenure (a fief), a cantonment, military suburb, a village.
Pálkulam	"*Milk-tank*"; fr. pál, milk, (cf. C. nál, and Gr. gala, milk).
Pallam	A ditch, hole, pit, ravine, water course, hollow, &c.
Pallan, pl. Pallar	A very low caste of labourers in S.I.
Palli	A hamlet, also a small town, a village: a fane, mosque, &c.
Palli-vásal	Com. use on the S. coast for a mosque, place of worship; fr. palli, a place of assemblage, and vásal, a door or gateway.
Palliamunei	Derivation. uncertain: n. of an island said to be named from the mainland of which it perhaps once formed a part.
Pámban	Fr. S. pámbu, a snake. Pr. n. of the town on Rámeswaram Island, at the channel, dividing it from the mainland.
Pámbár	"*Snake-river*". A small river of the Madura country.
Paneiyúr	"*Palmyra-ville*"; from panei, the Palmyra palm, and úru, a town.
Paneiyeri-Enthal	"*Palmyra-climbers' tank*"; fr. panei, v. sup. eru, climb, and enthal, a tank.
Pápánkulam	"*Brahmans' tank*". Brahmans are called pápa, and pápán, for párpan (? = "*Seer*") in S.I.
Pápanásham	Fr. S. = "*Sin-extinction*", a sacred bathing place near the lowest cataracts of the Támraparnei river.
Pár	(?) for párei, a rock, crag: a common affix to pr. n. of villages, &c.
Parambu	High ground, a stony mound, gravelly waste, a ridge.
Parapana-valasei	(?) "*Brahmans' retreat*"; see pápán, valasei, Tel. a retreat.
Párei	A rock, com. use.
Pareicheri	"(Vulg. Parcherry)"="*Pariah's hamlet*", or quarters; fr. pareiyan, an out-caste, drummer, and cheri, a hamlet, place.

Parutti	Cotton, the cotton shrub.
Párvati	Pr. n. daughter of Himálayah, and consort or Sakti of Shivá; also called Durgá, Devi, Bhaváni, Káli, &c., at Cape Comorin ("kanniyá-kumári=the virgin maid") where there is a famous old temple in her honour; she is also called Bhagavati.
Pattanam	Fr. S., a town, a city, a large town.
Patti	A cattle-fold, herdmen's village, a small village (=c. hatti).
Pattinam *	A town by the sea or on a river. A seaport town, (a port).
Peisás-mundel	Fr. S. pisácha="*Demon-cape*". The northernmost point of Rámeswaram Island.
Peria Kulam	"*Great tank*"; fr. periya, great, and kulam a tank.
Periapattanam	"*Great town*". This is said to have been an exceedingly large city some centuries ago.
Periúr and Perúr	"*Grand-ville*".
Perumál	"*Great one*"; fr. periya, great, and ál, a person. A common name for Vishnu in S. I.
Pettoi	A suburb, a town or village with shops, a market town, usually contiguous to a fort.
Pey-kovil	"*Devil's temple*". The Shánár (or Sánáns) and other low tribes worship a demon for god, i.e. a malignant deity.
Pillei	A child, son, a title assumed by some of the higher Tamil castes (cf. L. filius; fr. fil, &c.).
Ponthampuli	Pr. n. (?) fr. pontu, a hole, cave, and puli=tamarind (tree).
Pothikulam	"*Baggage-pond*"; fr. pothi="*full of sacks*", or packs. A tank where they unpack and rest, &c.
Poy-chal-lá-moyir-ayan-kovil	Pr. n. "*The lieless truthful* (i.e. *most true*) *lord's temple*".
Pú	A flower; also pushpam or pudpam from the S.
Pudu or puthiya	New, com. use. Pudúr="new town"; Pudu-kottei="*new fort*", (vulg. "*Poodoo-Cottah*").
Pudu-madam	"*New College*"; fr. the previous, and madam, a school or college for brahmans.
Pul	Grass.
Púlánkál	"*Púlám-branch*"; fr. púlám, a plant (the twigs of which are used for a toothbrush), and kál=a leg, properly limb-branch.
Puli	A tiger.
Puli	A tamarind (tree) sourness.
Pulieri	"*Tamarind-lake*"; fr. puliya (-maram) the tamarind (-tree), and eri, q. v.
Pulli	A spot, point.
Púmurichán	"*Flower-broken*"; from pú, a flower, (which the coral much resembles), and murichán=plucked or bruised. Name of a channel through the coral reef.
Puram	Fr. S. pur, purá and púr, a town, city, a considerable town with brahman inhabitants; waram, or veram is vulgarly used for this word, as in "Conjeveram", for Kánchipuram; "Mauliveram" for Mahá-bali-puram, near Madras.
Puram	T. a side, the outside: comly. applied to an outlying village, a suburb, com. T. affix to v. and pr. n. This word is said to have no connection with the previous "puram".
Putti Tívu	(?) "*Hummock Island*". Putti and pottol, are applied locally to shoals, reefs and sandbanks in the sea, cf. pottei, a mound or hillock, local usage.
Púvarasanshallitívu	"*Portia (-tree)-Shingle Island*", puvarasu-maram=the tulip tree.
Púvanáyakkanpatti	"*Púva Naik's fold*", (pronounced more like Boghanaikon-p.), a man's pr. n., and patti, a fold = a small village.
Raghunáthapuram	Pr. n. "*Raghunáth's town*".

Note.—In Northern India "Pattan" is frequent, on the rivers of the Panjáb, as Pák-pattan, Hari-ka-pattan, &c., and it is said to mean *a ferry* there (cf. H. patni, a ferry man); also on the "Jumna" and "Ganges"; e.g. Indrapat (?), Patna; also it is exceedingly common on both coasts of Southern India;—"*Seringapatam*" (Sri-ranga-pattanam) is on the river "*Cauvery*" (Káveri).

Rájákapáliam	Vulg. for Rájákal-páleiyam. Rájákal (plural of Rájá) = kings, and páleiyam, q. v., = "*Kings'ton*".
Rámaswámi-madam	"*Rámaswámi's College*", on the S. coast of Madura founded by a former zemindár.
Rámesweram	Fr. S., Rámá, iswara=God, and puram (=? "*The town of Ráma's lord*").
Rámnád	Pr. n. of the zemindári estate and the town com. called by the natives Rámá-nátha-puram (*Lord Ráma's Town*) for which it stands.
Reddi	One of a Telinga (or Telugu) agricultural tribe or caste, of which there are some colonies in Tinnevelly and Madura.

S. in Tamil stands also for ch, j, jh, and sh, and the Sanskrit ksh, and is pronounced and transliterated variously.

Sambutti-yendal	Pr. n. Eudal or yenthal, a small tank, com. in Madura.
Santoi	(Vulg. shandy) a fair. The com. weekly village market of S. I.
Sáyalakudi	(?) "*Belle-house*" com. pr. n. of vils; fr. eháyal, beauty, and kudi, a dwelling.
Se- son- sev-, &c. or Che- chen-, &c.	A com. prefix meaning red. See following.
Senchadaináthápuram	"*Red-shocked lord's-town*"; fr. sen, red, chadai, matted hair, nátha, lord and puram, town.
Sengalaneerodei	"*Red-water-course*"; fr. chengal (sen-kal, red-stone) neru, water and odei, a course (fr. odu=run).
Servoikáran	The title of the Ahambádiyan, tribe of Madura Tamils., hereditary servants or clansmen of the Sethupatis (Zemindárs of Rámnád).
Sethupati	"*Lord-of-the-causeway*"; title of the Prince of the Maravars, Zemindár of Rámnád; fr. chedu, a causeway = Adam's bridge, and the ancient causeway of Rámesweram.
Sevalpatti	"*Red-fold*"; fr. sivappu, red, and patti, a fold, village.
Shalli-Tivu	"*Shingle-island*"; fr. challi, broken pieces of stone, brick, shell, &c.
Shemanúr	Pr. n. perh. derived fr. Shapana, or Sámana, a Jaina sect in S. I.
Shera-mudali or muthali	Pr. n. for maulavi, a Muhammadan worthy, saint, or sage named Shera.
Shevelmedu	"*Red-mound*"; fr. sivappu, red, and medu, a mound, high ground.
Shivá or Sivá	The 3rd deity of the Hindu triad; Saivas regard him as creator, destroyer and regenerator, and worship him in the form of the linga, his type or emblem.
Soneiperiyán-Kottei	"*Grandee's-spring-fort*"; fr. shonei, a (water) spring, periyán=great one and kottei, a fort.
Sri	A name of Lakshmi, the consort or Sakti of Vishnu, goddess of prosperity, fortune.
Sundaramudeiyán	"*Beautiful-Udeiyán*"; fr. sundaram = beautiful and udeiyán, a title of the kallan tribe.
Suplápuram	Corrupt for Subramanya-puram = "*Town of subra-manya*" the Hindu Mars, god of war, son of Shivá.
Súrangudi	Pr. n. of a chief (súran = a hero; fr. S. suria, the sun), and kudi, a dwelling.
Taleimanár	(?) "*Head of Manaar*"; fr. talei, the head. The Ceylon end of Adam's bridge.
Taleiyáli	N. of an island; fr. talei, the head.
Támraparni	"*Copper-coloured*"; fr. S. támra, copper and varna, colour.
Tangamma-puram	"*Golden-lady-town*" (?).
Tani-chanthei	(?) "*Only-fair*"; (?) santei = a fair, market, (vulg. shandy). Old name Tani-cheyum.
Tanui-turei (? toni-turei, q. v.)	"*Water-ford*"; fr. tannír, water (prop. cool water), and turei, a ghát, ford, shore, &c.
Taravei	(?-vu.) A salt-marsh-swamp. com. use near the Madura coast.
Taroigudi	(?) "*Landham*", or (?) "*flat-house*"; fr. tarei, the ground, earth, a place, and kudi, q. v. (? a level place, flat).
Tattanadi	"*Parrot-river*"; fr. tattei, the green parrot, and nadi, a river.

Tedal or Tidal	High ground, a dry place in a river or marsh, a heap, swell of rising ground ; tidar, titei and tittu all mean very much the same.
Tekkei	Vulg. for terku (ton) south, southern, in oppn. to vada, north, northern.
Tenkadá	For ten-kadal="*south-sea*", a place on the south coast of Rámesweram.
Tenkási	"*South Kási*", or Benares.
Teppukulam	"*Raft-tank*"; fr. teppam, a raft on which the idol is floated about.
Teri or Theri	Local name for the drifting sand hillocks or red sand wastes of Tinnevelly and Madura.
Thalaváypuram	"*Field marshal's town*"; fr. Talaváy=Dalaváy, title of the commander-in-chief, or minister of a South Indian Native Government.
Tidar	(Tedal, q. v.) a mound, dry bank in a marsh or river, &c.
Tinnevelly	Vulg. Eng. for com. Nat. pron. Tirunaveli, wh. is for Tiru-nel-veli= "*Sacred-rice-hedge*". The town stands in the midst of rice fields.
Tiru	Blessed, holy, sacred ; a name of Lakshmi=good fortune.
Tiruchúr	(Vulg. "*Trichoor*") (?) corruption of "Tiru-Shivá-per-úrú" = "*Holy Shivá's great town*".
Tirumálugandán Kottei	(?) "*Shivá-server's fort*"; fr. Tirumál, Holy one, and ukandán, obeyed.
Tirupatúr	(Vulg. "*Tripatoor*") for Tiru-pati (vulg. "*Tripetty*")=sacred-lord, and úru.
Tiruppuláni	Pr. n.; fr. tiru, holy, pul, grass, and áni ((?)=wearing) fr. the legend of Rámá having once slept here on the sacred (sacrificial) grass.
Tiru	An island (on Coromandel Coast *tívi*, on Malabar Coast *tív.* and *div.*) fr. S. dwípa=two waters.
Tiyanúr	Fr. tiyan= low-born, base.
Toniturei	"*Boat-ferry*", "ship-ford"; fr. toni, a boat, and turei, landing-place, ford, road=ghát.
Tulkapatti	"*Turks-fold*". Tulukkan or Tulukkar, as Muhammadans are called in S. I.
Turei	A landing place, the ford of a river, the haven of a sea.
Tuticorin	Corrupt. for Túttukudi, q. v.
Tutti-nattam	Fr. tutti, a plant ("*Sida Mauritana*") and nattam a village.
Tutti	A trifle, insignificant.
Túttukudi	The native name of "*Tuticorin*", said to mean "*scattered-habitation*"="*winnow village*".

U final is so softly sounded in Tamil as to be nearly mute.

Umuriampádu	"(*Sea*)-*weed-shore*", (?) from the accumulations of sea-weed so common about here.
Uppár	"*salt river*"; fr. uppu, salt, and áru, a river.
Uppu-tanni-tívu	"*salt-water-island*", in oppn. to "Nalla-tanni-tívu" (q.v.) an adjacent island where good water (to drink) is found.
Uru or Ur	A village, town, country ; com. appd. to large villages of Canarese or Telugu people in Madura.
Uruni	A tank or well. The common village tank, accessible to all in the place.
Uth	Com. affix. (for úrru, prond. úttru) a spring, fountain.
Uttan or Vuttan	V. pr. n. (?).
Uttarakoshamangei	Pr. n., more fully, "Tiru-uttara-shri-koshamangei", a famous but decaying Shivá temple near Rámnád, about which there is a long legend.

V is used sometimes for b and w in writing foreign words in Tamil.

Vada	In comp.=north. By the English called Wada and Bada, e.g. Vadakarei, Wada-k. and Bada-k. "*North-bank*", *North-shore*.

Valam-bádal	(?) Perh. "Right (hand)-bádal", in oppn. to Idam-bádal, a vil. to left of the marsh close by.
Valasei	Tel.="*Removal*"=flight from home for fear of an army in the field,= "*a retreat*", com. n. of a village so occupied, Vulg. "Walsa".
Valoi Tivu	(?) "*Sword-fish-island*"; fr. vál-mín=the sword-fish.
Válinokkam	Pr. n. of a headland S. coast of Madura.
Varam or-Voram	Vulg. colloq. form of puram a town, also waram and weram.
Vásal	A doorway, entrance, gate; pallivásal, a mosque loc. use.
Vayal	An open plain, a field, C. bailu. The vulg. "bile," "byle", vail, and boyal, &c., of Eng. maps.
Veli	A hedge, ward, wall; com. affix to village names, as "Tirnaveli" see "*Tinnevelly*".
Medu Vellakára	"*White-man's-mound*"; fr. velli, whiteness.
Velloiyammanpuram	"*White-goddess-town*"; fr. vellei, white, ammál, goddess, and puram, a town.
Vembár	"*Margosa river*"; fr. vembu, the margosa or "*Nim*" tree, and áru=river.
Veppam-kulam	"*Margosa tank*"; fr. veppu, the margosa or "*Nim*" tree, and kulam, a pond or tank.
Vettilei-mandapam	"*Betel mandapam*", written Verrilei (rr prond. = tt) on the mainland opposite to Pámban.
Vijayápati	"*Vijayá's lord*", (i. e. Shivá) Vijayá="Victorious", a n. of Párvati: hence Eng. "*Beejapore*" (for Vijayápur) and "*Viziana-gram*" (for Vijayámanagaram).
Viláttikulam	(?) Viládti, occas. form of vilá=the wood-apple (Feronia Elephantum), and kulam, a tank.
Vilvamarattupatti	"*Bel tree village*"; fr. Vilva-maram (in comp. marattu)=the sacred Bel tree (cratava religiosa).

W is not a Tamil letter, but it is vulgarly pronounced before o initial and u sometimes.

In Tamil y is vulgarly inserted or pronounced before a and e initial.

Yánei or anei	An Elephant.
Yelavelankál	(?) "*tender thorn branch*"; fr. yel = tender, velam = thorn (tree) ("*Acacia arabica*") and kál, the leg, a prop, branch, &c.
Yenádi	Pr. n. = (?) "why-first"?
Yendal	A very small tank, or reservoir com. affix to pr. n. of villages in Madura.
Yervádi or Ervádi	Pr. n.; (?) fr. eru a buffalo, and vádi an enclosure, yard.
Yettiyal	Pr. n. (?) for yetti-vayal; fr. Etti = a bitter and poisonous tree ("*Strychnos nux vomica*") and vayal, a plain, field, &c.

ABBREVIATIONS.

C = "Canarese"; Gr. = Greek; H. = Hindustani; L.=Latin; M.= Malayálam; S. = Sanskrit; T. = Tamil; Tel. = Telugu; R.C. = Roman Catholic; S. I.=South India; N., E., S., W. = North, East, South, West; = means equivalent to; com. = commonly; fr. = from or derived from; n. = name; pr. = properly; t.= town; v. = village; besides others in more common use.

Extract from the Narrative Report—dated 23rd August 1875—of Lieut. H. J. HARMAN, R.E., Assistant Superintendent 2nd Grade, in charge Assam Valley Triangulation.

(1.) I arrived at Shillong from Bangalore on October 4th 1874 and took over charge of the Party from W. G. Beverley Esq., on October 6th 1874.

(2.) The Party left "Gauháti", by march to "Jorhát", on November 5th 1874, in charge of Messrs. W. J. O'Sullivan and J. O. Hughes. With a few men I took passage in a steamer to "Kamlábári" near "Jorhát" and made arrangements for fixing the Treasury building in "Jorhát" from the stations "Bor Bhiti" and "Phakwa Dol", by running ray traces from these points into "Jorhát".—The final rays were each 6 miles in length and were opened out by Messrs. O'Sullivan and Hughes.

(3.) Meanwhile I visited the stations of the side of continuation and the stations "Bor Ghop" and "Gohaingáon" which were selected last season: and on the sands of the river laid out a triangulation to give data for cutting the ray "Bor Ghop" to "Gohaingáon" and to the Revenue Survey Pillar on the banks of the "Dikhu". This done I selected the position for the station of "Melankur" and obtained the bearing that the right flank ray from "Gohaingaon" should have so as to skirt the forest which borders the old "Dhy Ali". I could not get to the position of the "Dimú" Station, but got near enough to warrant the ray being cut through at once as a final ray. This line was successfully carried by Mr. O'Sullivan, and he suitably placed the "Dimú" Station at nearly 6 miles from "Gohaingáon". I returned to "Sibságar" on December 2nd and as I was under orders to join the Military Expedition (which had already left "Naraipúr" for the "Daphla" Hills) I visited the parties at "Jorhát" and reported myself to Major Godwin Austen (in charge of the "Daphla Expedition" Survey Party) at "Borpathár" (campNo. 2) on the 12th December.

(4.) The force had but a short distance to march, and I did not anticipate being with it more than 6 weeks, but it so happened that I did not get back to my Party until March 3rd, on which day I reached "Disangmuk". Now I had directed that as soon as the rays to "Jorhát" were clear, the party should move on at once to "Sibságar" and work solely in advancing the approximate series, because I intended to return by "Jorhát", build the station there and take the observations for fixing it: this plan was frustrated, and the angles must be observed on the march up next season.

(5.) During my absence Mr. O'Sullivan was in command of the party, with instructions to observe to any new peaks not already fixed by Mr. Beverley, but an opportunity did not offer. The rays to the Revenue Survey Pillar on the "Dikhu" were cut. A length for the side "Bor Ali" to "Bor Ghop" obtained, but a mistake crept in, and the ray "Bor Ghop"—"Gauriságar" in consequence fell out a good deal; this ray was 5½ miles in length and had very heavy forest on it. The ray "Bor Ghop"—"Gohaingáon", 7 miles in length, passed entirely over grass country, except in the middle of the ray where it traversed a belt of trees bordering the "Darika" river. The rays on to "Melankur" station from "Bor Ghop" and Gohaingáon were carried up to the left bank of the "Brahmaputra", and the right flank ray from "Gohaingáon" to "Dimú" carried as before stated in para. 2.

(6.) On March 4th I crossed the river and cut the two rays on to "Melankur" till they met; the ray from "Gohaingáon" fell on the spot indicated on the chart, but the line from "Bor Ghop" was considerably out; the final ray to "Bor Ghop" was cut and the station of "Melankur" built by Mr. O'Sullivan (a post station requires 3 days to erect if the materials are near at hand). I ran a ray trace between the "Melankur" and "Dimú" stations, the cutting of the narrow gap took 15 men four full working days, but the final ray took 20 men 20 days, Mr. Hughes cutting the heavy forest extending from the "Brahmaputra" to the "Bolemár" river, a distance of 1 mile, while my detachment cut from the "Dimú" side to the "Bolemár". On this ray fell 2 miles of jheel, a formidable obstacle, traversed by elephants with very great difficulty. On March 15th I visited Mr. Hughes, who was then carrying a right flank ray from "Dimú" to "Tengápánia"; this line was for the first 1¼ miles clear, being across a jheel, then came a huge cane forest for ¾ of a mile up to a jheel full of trees of extreme hardness, and the men were working up to their waists in water; I found Mr. Hughes far from well, he had written to say that he feared he would not be able to stay out the season, and some cases of sickness were showing in his detachment, so I removed this party to the banks of the river and Mr. Hughes cut the forest portion of the "Melankur"—"Dimú" ray as above mentioned.

(7.) I had not been able to visit "Tengápánia" before I left for the "Daphla" Hills, nor had Mr. O'Sullivan the opportunity subsequently, and from a misconception of my letter of instructions, in which I wished the rays to "Melankur" to be completed before advancing, this ray was undertaken without a reconnoissance having been made, and it landed us in trouble; finding so much labor had already been expended on the line I did not like to desert it as in 3 miles more it would cross the old Assamese raised road, the "Dhy Ali;" so on March 17th my party shifted to the head of the ray;

the two following days I was on the line and we worked very hard, but accomplished 220 yards only; the jheel cane was terribly armed with crooked thorns on every surface, I have seen no cane like it elsewhere: the natives with their wooden sandals and naked legs could barely creep through the fallen stuff, and they suffered severely. On March 20th I left my party on the ray, and with a few men went to reconnoitre "Tengápánia": the tract of country between the "Dimú" river and "Tengápánia" is intersected by the "Bolemár" river, several streams, and the old "Dhy Ali"; and has not been surveyed by the Revenue Survey, so to find where the ray would emerge on the "Dhy Ali" I ran a traverse from "Lasun Mirigaon"; this done we dragged a boat, through the forest and I went down the "Bolemár" and decided to carry the line on.

(8.) I then selected the stations of "Kherkutia" and "Sisa" and gave off the ray "Melankur"—"Kherkutia", which Mr. O'Sullivan carried, building the station close to the spot selected. I measured a base on the sands of the river and laid out a plan for triangulating this side, which work Mr. Hughes executed and I also measured another long base at "Lasun" to connect on with this work and to find the sides "Kherkutia" to "Sisa". Mr. Hughes now took up the ray "Kherkutia" to "Dimú", of which I had already cut a part from the "Dimú" side, leaving 2½ miles of forest and cane to be cut by Mr. Hughes from the river side.

(9.) On April 1st I returned to "Disangmuk" and reported to you my intention of at once taking up observations on the 4 triangles now ready; but reports came in, that the "Tengápánia" ray was still in cane, though better progress was being made. The spring rain set in violently, and I got news that an elephant had been lost in the jungles about "Dibrugarh" for five days; so taking some men I went up to "Dibrugarh"; the river rose rapidly and I was able to take my boat everywhere and so selected the 7 stations necessary to carry the series on to "Dibrugarh" Church tower, and see the country well.

(10.) On April 11th I returned to "Disangmuk", and found that my Jemadar, 2 elephants and men from the "Tengápánia" ray, had not returned as ordered; they had not been heard of for 7 days and as it had been raining heavily since April 1st, and all the rivers were up and the country flooded, I went the next day in search of them; we had rather a rough time of it, but on April 17th were all safely back at "Disangmuk". On my journey I visited Mr. Hughes' ray "Kherkutia"—"Dimú" and found it had gone a mile and was in heavy forest and cane. On April 22nd Mr. O'Sullivan crossed the river from "Sisa" to aid Mr. Hughes in pushing on this line. On April 25th the ray suddenly got flooded from the overflow of the "Bolemár", and a few days afterwards as the water was still up, I directed that the work should close there for the season.

(11.) The forenoon of April 21st I left "Disangmuk" to observe the 4 triangles ready, and so much water was then out that it took us till nightfall to get over 5 miles of the path to "Sibságar." As expected I could not encamp within a mile of any of the stations "Gohaingaon", "Bor Ali" or "Bor Ghop". I had put off taking observations till so late because from December to March they cannot be speedily done, and I thought it most important I should examine the country ahead, and get all the stations selected this season up to "Dibrugarh", if possible. I was delayed at "Gauriságar" on account of the branch of a tree on the ray to "Bor Ghop" cutting the heliotrope and giving a grazing ray; and also at "Bor Ghop" on account of the heliotrope at "Gohaingaon" not being visible at the time of minimum refraction; it was difficult to remedy these defects, as all the lines were under water, so after having visited 4 stations and obtained the elements of the side "Gauriságar" to "Gohaingaon", from which the Topographical Survey were taking their triangulation into the Nágá Hills, I closed work on May 10th and dropped down the river "Brahmaputra" in my boats to "Gauháti", reaching that place on May 16th, the same day that Messrs. O'Sullivan and Hughes arrived by steamer from "Disangmuk", the steamer having been greatly delayed.

(13.) Mr. O'Sullivan managed the party satisfactorily while I was in the "Daphla Hills". The amount of final ray opened was 49 miles of which 6 miles were in forest, 30 over Chapori jungle, and 3 of village cutting; he selected the "Dimú" station and built excellent post stations at 3 places.

(14.) Mr. Hughes opened out 20 miles of final ray of which 7 miles were in heavy forest, 7 miles of light work and 2 of village clearing: built good post stations at "Bor Ghop" and "Dimú": built the high platform for showing a heliotrope above "Phakwa Dol", and observed the angles for measuring the side "Melankur"—"Kherkutia" and for correcting the trial ray "Jorhát" to "Phakwa Dol".

Mr. Hughes has not worked this season in the manner I wished and had shown him; on most of his rays the work expended has not been at all judiciously applied and the labor has been excessive.

(15.) A man mounted on an elephant can rarely see over the surrounding grass, or whatever it is; so I tried to introduce the plan of aligning the main flags by the parts of the flags which overtop the grass, and not by the lower half of the flags which is the usual custom.

A tiny gap is carried as straight as can be done with small hand flags placed at very short intervals, and at every half mile a man ascends a small portable bamboo frame so as to overlook the grass

and plant a tall flag in the alignment with the back tall flags: this method obviously requires the least grass cutting possible: I have tried the method and with success; but this season, owing to Messrs. O'Sullivan and Hughes being sick and unable personally to superintend the cutting it has not been employed: again, in carrying a trial ray through forest it is plain that large trees should be avoided by shifting the line a foot or two parallel to itself, but for the same reason this has not been done; so that with exception of the ray "Molankur"—"Dimú" all the rays have been cut through as final rays, which is in great measure the cause of the small progress made, especially as the stations and the heliotropes are placed above the line of grass and the only obstacles are the trees. Before leaving "Gauháti" the establishment were put through a course of trying frames of cut bamboos, and any 12 men could construct and erect a stiff frame 50 feet high in 40 minutes, of course 50 feet is never necessary, 20 to 25 feet suffices in almost every case.

(16.) The district worked in this season (excepting "Golaingaon" near "Sibságar") has only a small "Miri" village here and there; no local labor worth mentioning was available or procured: next season the "Miri" villages will be fewer in number; when nearer "Dibrugarh" the Commissioner will make special arrangements for us. There are no roads, only one or two paths were found of use; the main communications are the river and the rays cut; for the former, boats larger than small dug-outs are very scarce and men not easily found to work them, and a ray cut through forest is almost impassable for elephants. Provisions have to be entirely supplied to the parties at work from depôts where they are collected, so that to maintain local labor and move it on the work is rather a task. The leeches in April and the swarms of mosquitos about the middle of April were great plagues.

(17.) Of the ray "Kherkutia"—"Dimú" 1 mile remains uncut and of the ray "Dimú"—"Tongápánia" 1½ miles: when this work is done, there will be little cutting on the left bank of the "Brahmaputra", the whole of the remaining lines into "Dibrugarh" are over Chapori jungle, chaurs, and the river.

(18.) We came across several old Assamese embankments and "Alis" (roads) on our lines this year, all covered with tree forest, they are not shown on the maps. While travelling in my boat up one of the jáns (small deep streams) north of the "Dihing" river in search of a suitable site for a station I came upon the trijunction of 3 old "Alis" in the thickest tree forest, but whither they led the "Miris" who accompanied me could not say. Near the "Tongápánia" station is the junction of the "Dhy Ali" and the "Motiárigarh" (old embankment), and the angle is curiously enclosed with a great circular road.

(19.) The out-turn of area this season is insignificant, but I hope, Sir, you will take into consideration the many retarding influences we had to contend with.

Extract from the Narrative Report—dated 22nd September 1875—of W. C. ROSSENRODE, ESQ., Deputy Superintendent 3rd Grade, in charge Eastern Frontier Series.

(3.) Owing to the difficulty of obtaining carriage and the country being still under water, I sent on the baggage and some provisions in charge of the tindel on the 7th November 1874, to Jungjungia, which was to be my first station of observation.

(4.) I left Moulmein on the 19th November, accompanied by Mr. Beverley, in boats, reached Sittang on the 30th November, hired boats at once, and joined my camp at Jungjungia H.S. on the 1st December.

(5.) On the afternoon of the 1st December the men who had gone to Suplitong H.S. with the signal party, returned with the intelligence that they could not find the path to ascend the hill, nor could they induce the villagers to accompany and guide them. The guide took them to the foot of the hill and would go no further, for fear of losing himself in the dense grass and tree jungle. I manned a fresh party with axes, billhooks and sickles and ordered them to cut their way and get up to the station as quickly as they possibly could, without waiting or trying to obtain aid from the inhabitants. To wait for assistance was hopeless. Suplitong H.S. is so situated that for 20 to 25 miles in every direction there are no villages.

The party I sent cut their way up and reached the station on the 6th day after leaving camp, and directed their signals the day after clearing the jungle on the summit.

(7.) The observations at Jungjungia H.S. were concluded without further interruption on the 11th December, Kuladong, The-ye-khu, Myayabengkyo, Kaneindong, and Keokpondong Hill Stations were then visited in succession. From Keokpondong H. S. I had to march to Kambangun Tower Station. The route lay through the extensive Pegu plain covered with reed and grass jungle: this during the rains

is an immense swamp and it was still wet. Even in the middle of January some portions were impracticable for elephants. The march was circuitous and difficult and occupied 7 days, the direct distance from station to station being only 26 miles.

(8.) On completing the observations at Kambungun Tower Station on the 25th January 1875, I marched the next day and arrived at Chaiteo H.S. on the 1st February. A description of it is necessary, this hill being held in great sanctity by the Burmans and all the other tribes in the Province.

(9.) Chaiteo H.S. is 3000 feet above sea level. Stupendous projecting rocks, surmounted with masses of rock, rivet the attention of the traveller on his attaining the summit of this mountain, and he is lost in thought and speculation at the wonderful phenomenon which presents itself. The priests assert that superhuman agency alone has accomplished the miraculous lifting of these huge masses of rock in successive tiers, and that the gods who executed the work, reside beneath them. Each of the above rocks is crowned with a pagoda dedicated to Gaudama the Budhist Deity, and the Burmans, Shans, Karens, and other tribes, make pilgrimages from all parts of the Province to the shrines (pagodas) constructed on this sacred mountain.

(10.) The Principal pagoda, named Chaiteo, is constructed on a rock overhanging the south-western face of the hill; directly below it is a yawning precipice several hundred feet in depth. The pagoda as it stands on the rock overhanging the precipice gives one the impression on seeing it from a distance that it is poised in mid air. On approaching it however the rock, an immense one, it is seen, has firm hold of the hill side and projects like a rhinoceros horn over the precipice. On this projecting portion the pagoda has been constructed. This is the principal and most sacred pagoda in which are deposited the bones and a tooth of Gaudama. There is nothing artistic in the edifice itself, the nerve and courage of the artificers commend themselves to the admiration of all visitors who are able to appreciate these qualities. The pagoda is roughly constructed, its defects however are hidden by the covering of gold leaf over a thick coating of some black looking adhesive substance which is prepared by the Burmans and used for this purpose to obtain a smooth surface. This substance consolidates and adheres most tenaciously to the structure and the gold leaf put over it is so tenaciously grasped by it that when dry it becomes a solid mass difficult to remove.

There are several other pagodas which have their history, and the pilgrims visit each in succession daily during the dry months from December to May. A grand festival is held annually, during March and April. The day of the full moon in March was this year the grandest day of the festival. Prior to the commencement of this carnival, sheds and booths spring up in all directions all over the hill, constructed by one or more members of each community, for the accommodation of themselves and their families. Traders have their stalls well stocked with every requisite and fabulous prices are realized by them, the demand increasing as the days run on towards the termination of this festive season. To obtain a blessing, it is necessary to worship at each pagoda and each pilgrim must at all times use a lighted candle during worship, the consumption of candles is therefore enormous. They sell at 4, 6, 8, 10 and 12 annas each, the former prices are obtainable during the first month, and the latter during the succeeding month. After the expiry of the two months, the festival concludes and the pilgrims retire to their respective homes. Near the principal pagoda is a fissure in the rock, about 4 inches in width, 7 feet long, and 15 feet deep, into this offerings are cast, consisting of silver and copper coins, gold leaf, (beaten gold) rubies and other stones of lesser value. This fissure is the treasury box of the Budhist Deity Gaudama. On the pilgrims retiring, after making their offerings, men with long thin rods with bird lime attached to the ends, endeavour to secure for themselves the coins and other valuables cast into it, whatever adheres to the rod is brought up and appropriated. Cloths of cotton and silk are also offered, should the cloth be of great length it is wrapped round the pagoda, the smaller pieces do duty as flags, streamers and banners. Cocoanuts and plantains and food are the usual offerings to the priests and monks.

(11.) A well 20 cubits deep has been sunk near one of the pagodas, this feat was accomplished by a single man working daily for 6 years through the rocky strata; he was rewarded for his patience and perseverance by hitting upon a spring which provides a plentiful supply of water, and the well has never been known to be dry.

(13.) After completing the observations at Chaiteo H.S. I had to visit Toungoomdong H.S. The routes to it were very circuitous and would have occupied me 9 and 10 days to reach the station. I ascertained that an old road through the hills was still partially in use which would save me 5 stages. I had this path, for it was nothing more, cleared, widened, and the overhanging branches removed, and although the marching was difficult and tedious and occupied 8, 10 and 12 hours daily, I saved 5 days by adopting it.

(17.) Suplitong H.S. was dreaded by every man in the native establishment. They had heard how Mr. Beverley had fared there the previous season; how the men with the signal lamps and heliotropes had been detained in a howling wilderness, in the early part of the season, until re-inforced by me;

how the men I had sent out their way up to the station; how members of this party had returned sick and disabled, and suffered from fever for 2 months, one having died a raving maniac from fever contracted there; how Mr. Clancey who had cut the road, nearly succumbed from fever and how all his men, public and private had been prostrated and sent to Hospital, one having died there. His servants and Interpreter had deserted, and another Interpreter I had sent him had taken his discharge. The exaggerated accounts given by the men who had been there, of the dangers and difficulties to be encountered on the journey to Suplitong made such an impression on the minds of the men of my camp, that they dreaded the idea of going there. Disheartened and desponding they commenced the march. They were well fed and cared for. The preparatory arrangements had been well made for going and returning, the healthiest time was chosen after the jungle had been fired, and the difficulties and dangers, which were so appalling became less and less as the camp proceeded onwards. The summit was attained, the theodolite put up and the observations were completed the third day and we descended the hill returning by the same road and encamping at the same spots.

(19.) From Suplitong I proceeded to Thulu H.S. which I reached on the 10th of March making 12 consecutive stages. Owing to smoke and haze, the observations were not completed until the 21st I then visited Chaideo H.S. where I was detained 7 days from bad weather.

(20.) From Chaideo I visited Kyunkaban Station situated near the mouth of the Bheling river, here I was detained 8 days. The ray from this to Kalamatong H.S. was 32 miles in length and passed over a large expanse of water, the signals were at first unfit for observing; when the weather cleared up I succeeded in getting good signals and completed the observations. This was a most uncomfortable station to encamp at. Standing as it did close on the bank of the Bheling river, near its mouth, in dense tangled jungle difficult to cut and difficult to penetrate. The spot selected for the station was the highest available. A circular clearance of a hundred yards was made for the encampment. The elephants horses and the sick under the Native Doctor were located in a village 4 miles away.

(21.) I arrived at Kyunkaban Station on the 4th April during the spring equinox. Two days after the sun was partially eclipsed. The spring tides on this occasion were unusually high. The first washed over the encampment and submerged it, the platform was the only dry spot, upon which all the baggage, provisions, and other valuables were placed. As soon as the tide receded, a strong scaffold 15 feet high was erected for the baggage, and the tents were pitched upon raised scaffoldings 4 feet in height. It was most fortunate that no storms occurred during my stay at this station, for had one broken upon us and raised the water, as storms generally do, to a great height, we should one and all have perished, for there was not the remotest chance of escape encompassed as we were by tangled and impenetrable jungle, by the river and by two creeks, which would have proved formidable barriers.

(24.) There is a bar at the mouth of the river and the bore here is more formidable than any I have witnessed in other tidal rivers.

(25.) From Kyunkaban I proceeded to Kathbatong H.S. the centre of the next hexagon; owing to the smoke and haze with which the atmosphere was impregnated, observations proceeded rather slowly. The monsoon set in on the 21st April, with storms and rain, its usual accompaniments. The heavy down pour ushered in fine observing weather and I completed my observations and pushed on to Kalamatong which I reached in four days. Notwithstanding daily showers of rain, I hurried on not to lose the fine weather following rain, but on arriving at Kalamatong I found myself enveloped in cloud and mist. The rains had set in from the first shower which fell on the 21st April, every day was wet and the clouds and mist delayed me greatly. I took advantage of every break in the weather and completed my observations on the 13th day after my arrival.

(26.) There had been no rain from November to the 20th April, and I naturally expected a long break of a fortnight or three weeks duration between the first showers, and the regular setting in of the monsoon, which bout of good observing weather, would, I had hoped, enable me to complete the Kathbatong hexagon. In this however I was disappointed I could not visit the two remaining stations of this hexagon owing to the daily rain and the country becoming gradually submerged and Kalamatong which was the highest mountain for miles around, being generally capped with clouds; no signals from it to Mizantong with which it is connected, could be obtained. I had no other alternative but to close work and return to recess quarters.

(27.) In a densely wooded country, sparsely inhabited, without roads, the time occupied in marching alone is considerable, 85 days were this field season spent in travelling. The routes from station to station are circuitous, the tortuous course of the hill streams being generally adopted to save time and expense in cutting new and direct roads. Labor is the great drawback in Burma. It cannot be obtained, the inhabitants, as a rule, are unwilling and disinclined to work. The laboring classes all over India readily present themselves, when work offers, to add to their comforts, by earning as much as

they are able. The Burmans are too lazy to do so, and throughout the Province, they themselves engage the Madras and Chittagong coolies to plough their lands and reap their fields.

(31.) During this season the positions of the following towns have been determined, Shoay-gheen, Sittang, Chaito, Bhiling, Thatone, Moulmein, Amherst and the Great Pagoda in Pegu. I find that the observations taken at Thelakitong in season 1869-70 to Pegu Pagoda were incorrect, some other Pagoda was taken and an erroneous position was therefore assigned to it. The observations taken at Sanwinguntong during season 1869-70 were correct. This season the Pegu Pagoda was observed from five Principal and one Secondary station. Many Pagodas have been fixed and the positions of a great many more will be determined during the ensuing season when the two remaining stations of the Kathbatong figure and some of the stations of the Makbo Pentagon are visited. To secure as much secondary work as I possibly could, I engaged a Native Recorder, and was thus able to detach Mr. Clancey.

(32.) There was less sickness this season than the previous one, the average number of sick was 8 in my camp and 4 in Mr. Beverley's. There were 5 casualties. Three men were sent home, their recovery in this climate being hopeless, owing to continued debility and emaciation from fever.

(33.) Mr. Henry Beverley, Surveyor 1st Grade, has been engaged the whole season on approximate work. He commenced work by selecting the stations of Toungoundong and Thulu. He then proceeded to Sittang and constructed the pillar at Kámbúngún in the plains, surrounding it with a wooden platform 16 feet square and 18 feet high. He then constructed the wooden scaffolding over Chaideo rock, 26 feet high. Every description of work takes time to accomplish in this Province, and the construction of the above pillar and two wooden scaffoldings, detained Mr. Beverley from 13th December to 20th January. Had Colonel Brown, the Commissioner of Tenasserim, not interested himself, by personally addressing the Extra Assistant Commissioner (a Burman), Mr. Beverley would have been delayed much longer than he was.

(35.) On completing the above, he resumed approximate operations, and selected two simple figures, a Hexagon and a Pentagon, and closed work at Sendong H.S., after having fixed most of the stations of a compound figure in advance. Owing to the setting in of the rains this latter figure could not be completed. Some of the sides of the compound figure are long owing to Mr. Beverley's having no choice of ground, the isolated, inaccessible lime-stone hills rugged, jagged and fantastically shaped, in the valleys of the Atteran and Wiang rivers, being hopelessly unsuitable.

(36.) I had directed Mr. Beverley to observe all Pagodas, which were visible at each station that he visited, and to use his best endeavours to determine the position of the Pegu Pagoda. He was successful in seeing it from Thulu and Shoay-yongbia Hill Stations. He selected and constructed a station at Amherst which was finally fixed by his observations there and at Toungzun, and my angles at Kalamatong H.S. Mr. Beverley also contributed some secondaries, while carrying on approximate operations, and many other Pagodas, which he has observed in advance of the final work, will be fixed during the ensuing season when I visit the Principal Stations.

(37.) The lime-stone ranges of hills on the eastern flank of the Series are mostly precipitous and inaccessible and Mr. Beverley had great difficulty in fixing suitable stations. He had to abandon Zway-ga-bèng and other hills more favorably situated, because the 24-inch Theodolite could not be carried up. With all his picking and choosing, he was compelled to adopt two of these difficult hills of lime-stone formation Mizantong H.S. and Makbo H.S., which with the aid of ladders and ramps, he managed to ascend. As this Party has, during its progress, encountered difficulties of every description, and every variety of ground, these two hills need not cause anxiety.

(38.) Mr. Beverley has accomplished a very satisfactory season's work. He lost the most favorable time of the year from the 13th December to 20th January in preparing the pillar and scaffolding at Kámbúngún and Chaideo stations; notwithstanding this loss, he with his usual zeal and energy advanced the approximate triangulation 100 miles of direct distance in a trying and difficult country with commendable cheerfulness and alacrity.

(41.) Mr. Clancey has worked well and satisfactorily. He takes much interest in his duties, and is assiduous to please. He has learned the Burmese language which will be very useful to him.

Extract from the Narrative Report—dated 13th September 1875—of W. G. BEVERLEY, ESQ., Officiating Assistant Superintendent 2nd Grade, in charge of the Burmah Party.

(2.) The Party was constituted under Departmental Order No. 44 of 6th August 1874, the establishment being transferred from the late Brahmaputra Series. Its object is to carry chains of secondary triangles from principal sides of the Eastern Frontier Series, in order to fix all the large towns, prominent and permanent objects, peaks, &c., in the province of British Burmah, for detail and Geological Surveys, and the light-houses &c. along the coast, for the Marine Survey.

(3.) A part of the establishment and heavy baggage left Calcutta for Rangoon with Mr. Collins on the 1st November; and the remainder with me on the 7th. Mr. Mitchell was transferred from the Eastern Frontier Series, and joined the Party at Rangoon. Work was commenced before the end of the month.

(4.) During the preceding season, Mr. Mitchell had in connection with the Eastern Frontier Series reconnoitred the country, and laid out an approximate triangulation from the principal side Keokpongdong H.S. to Kanoindong H.S. down to Rangoon, so as to fix that town, as well as Pegu. I considered it advisable, on commencing work, to examine Mr. Mitchell's selections and found it necessary to modify his plan to some extent, to save time in clearing rays and hill tops.

(5.) On my return from examining the country to the north, I took up the triangulation southwards to the coast, selecting stations after a careful reconnoissance of the ground. Most of these stations are fixed on old Pagodas, by which there was a great saving of time as regards ray cutting, and of expense in building stations. The approximate work of selecting stations, and the final work of observation, were carried on together as far as practicable. The triangulation was carried down to the mouth of the Rangoon river.

(6.) Mr. Collins had been left to clear the rays at the hill station of Ayodong; and as he had now nearly completed his work, I returned to take up the final observations from the stations north of Rangoon, as the atmosphere which hitherto had been pretty clear was gradually getting hazier, I went up as far as Taongnio H.S., but as Yomá H.S. in advance had not been cleared nor occupied by the signalmen, I was unable to complete my observations there. The angle at Cháglibá H.S., between Ayodong and Taongnio stations, could not be observed, as the signalmen had been compelled to abandon the latter station on 4th March, from the only spring there having ceased to run, and there being no water known to exist within 10 or 12 miles.

(7.) The triangulation from Taongnio and Cháglibá to the coast is incomplete; as the very dense haze, which prevailed from the beginning of March, prevented the requisite observations being taken at Ayodong, Cháglibá, and Shántoji, as shown by dotted lines in the chart accompanying. Two attempts were made after the rains set in to obtain observations, but without success.

(8.) The triangulation along the coast towards China Bakir light-house, was resumed in the middle of March; but from the nature of the ground the progress made was slow. Work was closed on the 24th of April, when the southwest monsoon set in with severe storms, and very heavy and continuous rain. In fact, the country had been gradually getting under water along the large streams, from the rising of the Irrawaddy river since the middle of March, when the snow at the sources begins melting. The cutters were frequently up to their waists in water, and suffered great inconveniences from the absence of drinkable water under a burning sun.

(9.) Mr. Mitchell at the commencement of the field season, opened the ray Chanakpho H.S. to Insingpaiá Station, and partially cleared the hills of Ayodong and Taongnio, taking some observations at the latter station. He took up the clearing of the ray Chanakpho to Ayodong, which was ultimately abandoned: he also took some final observations at Insingpaiá.

(10.) As there were no means of reaching Yomá Station directly from Taonguio, but by a circuitous route which would occupy nearly a fortnight, Mr. Mitchell was deputed to clear the summits of Kamhútong and Yomá, selected by him the previous year, to build the stations there, and commence final observations from the side Kánoindong H. S. to Keokpongdong H. S., closing on the stations of Taongnio and Cháglibá to be visited by me. This was partly in conformity with the plan laid down by himself, and which, from my examination of the country, appeared to be feasible. Mr. Mitchell, however, after a second examination of the country, and after visiting 3 or 4 points where he took rough observations, found numerous difficulties in so carrying the triangulation, and was obliged to resort to the side Kámbúngún T.S. to Júngjúngiá H.S. from which he thought he could get over the country more rapidly.

(11.) Mr. Mitchell took observations from seven stations; but owing to very bad weather and frequent attacks of illness, he was unable to carry his final observations up to the point where they

would have been connected with the work executed by myself. He endeavoured, at risk of health and much inconvenience, to complete his work by remaining out until the middle of June, when field work was impossible from the incessant rain.

(13.) Mr. Collins was employed in clearing the stations of Chánglibá, Engtago and Ayodong, and building masonry pillars on them. The forest at the latter station was extremely dense, and the rays from it to Insingpaiá and Shánteji were cleared over three broad wooded ranges. Upwards of a month was occupied at Ayodong alone. The delay was chiefly due to the difficulty of procuring labor. Burmese coolies could not be obtained after the middle of December, and the immigrants entertained were almost useless. Several of these latter deserted shortly after obtaining an advance of pay; while those from the immigration office contained a large percentage of Brahmins, who systematically abstained from any and every kind of work on the pretence of illness.

(14.) When the rays at Ayodong were all cleared, Mr. Collins took some final observations there, and also at Kaiúngálo Station with the 8-inch theodolite, and then proceeded and built a masonry pillar at Shánteji, but could not get observations, on account of the haze which had now become unusually thick. He joined me on the coast at the end of March, and was employed in carrying rays, &c.

(15.) Mr. Collins has throughout the season shown a great deal of zeal and energy, is a good and careful observer, and is rapidly becoming an efficient surveyor.

(16.) Two Burman interpreters and writers were entertained for this Party. One of these with Mr. Mitchell, died from fever in the field. The other was of very great service to me.

(17.) The men of the Native Establishment have worked well and cheerfully although in a new country and ignorant of the language and customs, and have given satisfaction. They are trained men selected from the Establishment of the late Brahmaputra Party, and sent to Burmah on higher rates of pay, but still much less than the pay given in this Province, and in some instances less than that given to the same class of men in the Eastern Frontier Party. In spite of the inducements of less work and very high wages offered in the Public Works Department, they have remained faithful to their agreements. The elephant keepers alone have been as usual with that class of men a cause of trouble and annoyance, and anxiety for the health and safety of the animals in their charge.

(18.) The triangulation has been carried over a variety of ground. The hilly portion is low and densely wooded, and the difficulties peculiar to this tract have been fully pointed out by Mr. Rossenrode, and noticed by yourself in your last year's Report to Government. These difficulties were to a certain extent greater to our Establishment which was quite new to the Province. The country along the coast is an equally difficult one for triangulation. It is low, and cut up with numerous tidal creeks and rivers. There are few or no paths through the low thick tamarisk and thorn jungle; and no drinkable water except at the villages which are small and far apart. The work on the coast can only be done by boats and coolies, both to be entertained at Rangoon, as they can rarely be got in the villages, and then only at exorbitant rates. Elephants cannot be used on account of the scarcity of fodder, and small supply of water procurable. The ground too, after inundation at every high tide, is extremely dangerous for laden animals.

(19.) The out-turn of work for the past year, would have been more satisfactory if there had been no break in the triangulation; and as the members of the Party are now better acquainted with the peculiarities of the country and people, a greater out-turn may be confidently expected in the ensuing field season, under favorable circumstances. The chief causes of delay in Burmah are the difficulty of procuring labor, and in moving with rapidity from one place to another; but the greatest is the haze arising from the burning of jungle and rice straw. On the coast, there is less haze to contend with, as there is very little jungle that can be burnt for clearings. Very little rain falls during the dry season: between the 7th of November and 23rd of April, there were only two slight showers.

(20.) There was much sickness in the camps at the commencement of the season; and both Messrs. Mitchell and Collins, and nearly every man of the Establishment, have suffered from malarious fever. In fact, there was always a large percentage of sick throughout. Three deaths occurred.

Extract from the Narrative Report—dated 16th August 1875—of Captain M. W. ROGERS, R.E., Officiating Deputy Superintendent 3rd Grade, in charge Jodhpur Series.

(2.) I returned from furlough on the 28th October, and on the 20th November relieved Lieutenant Hill, R.E., of the charge of the Party which he had held during my absence.

(3.) All arrangements for the field season had been made by Lieutenant Hill and he had sent off the assistants before my arrival. I had engaged the carriers for the Great Theodolite whilst at Ahmedabad and there was therefore no delay in taking the field which was done on the 23rd November.

(4.) I marched *vid* Jodhpur to Nok H.S. in Jaisalmir, where observations were commenced on the 17th December; from thence the observations were carried on continuously through the heart of the great Jaisalmir and Bikanir desert as far as Marot in Bahâwalpur and were closed at Bhulan H.S. on the 21st of March.

(5.) The following is a general statement of the season's work. Observations were taken at 25 principal stations forming a pentagon, two hexagons, and one double polygon, fixing 23 new principal stations, embracing an area of 2472 square miles, and extending the series 104 miles along the meridian. An azimuth was observed at Mugrálá H.S. to two circumpolar stars. The Approximate Series was extended 64 miles to its junction with the Sutlej Series. The positions and heights of Bikanir and Pugal were fixed by minor triangulation, the area of which, exterior to the series, was 681 square miles.

(6.) Some explanation is needed as to the dearth of secondary and intersected points; this is due to the nature of the country, in which there are neither natural nor artificial objects of interest.

The total intersected points on the principal series were 8, of these 7 were intersected from the four last stations of the series, leaving a tract of about 90 miles by 30, in which there was only one point which could be intersected.

Mr. Price.

(7.) Mr. Price was in charge of the Approximate Series and extended it through the desert to the Sutlej Series. Bearing in mind the great difficulties of the country, I consider the amount of work he has done and the well proportioned good figures which he has been able to obtain, reflect great credit on his zeal, intelligence and hard work.

Mr. Torrens.

(8.) Mr. Torrens laid out and observed a minor series to Bikanir by which that city was fixed in height; he closed on to a side of the series emanating from the Gurhágarh, with very satisfactory agreement in results. He also fixed the position of Pugal by a short series and the Revenue Survey trijunction at the junction of the Bikanir, Jaisalmir and Bahâwalpur boundaries. He also closed 17 stations in Bikanir and Jaisalmir.

He observed with a 10-inch theodolite and his average triangular error was 1″·7. He has worked well and cheerfully and I am much pleased with the quality and quantity of his work.

Mr. Prunty.

(9.) Mr. Prunty joined the party from Head Quarters during last recess, and accompanied me during this season as observatory recorder. He is painstaking, willing and neat, and has now acquired the accuracy which was all he needed to make him a very good recorder. He has learnt the use of the theodolite and perfected himself in departmental routine and I am very well satisfied with him.

(12.) The country through which the series passed this season, is a sandy desert; the sand hills in Jaisalmir are from 50 to 150 feet in height and are distributed in such a confused manner over the country as to make it a work of great difficulty to select stations or to obtain any but very short sides. Towards the north, in Bahâwalpur, they diminish in height and become merely mounds of drifting sand, interspersed with open spaces of hard clay which are perfectly level like the beds of immense dry tanks.

(13.) The sand hills of Jaisalmir and Bikanir are covered with high coarse grass, which grows in large tufts, and with shrubs, of which the most common and largest is the Phog, a leafless shrub, from 5 to 8 feet in height with green twigs and pleasant smelling flower.

(14.) In the Jaisalmir desert there is a good deal of cultivation mostly "bájri". Most of the numerous small valleys formed by the sand hills are ploughed and sown, although miles from any village, and I believe that the grain produced is very good.

(15.) The villages are few and far apart; attached to each are numerous "dhánis", that is two or three huts erected in the desert, wherever there is either a well of brackish water or a small excavation

in the hard soil (which crops out at intervals) in which water collects during the rains. These 'dhánis' are inhabited during the rains and cold weather, when the desert is comparatively populous, but are deserted in the hot weather, when the inhabitants return to their villages.

(16.) In the portion of Bikanir, through which the series passed, there is hardly any cultivation. The occupation of the inhabitants is almost entirely pastoral, and they have large herds of cattle, sheep, goats and camels. From Pugal in Lat. 28½° to the valley of the Sutlej, with the exception of the villages lying on what was the bed of the old Hurkara river—about 40 miles south of the Sutlej—there are no villages and only a few wells of brackish water; this tract is the most desolate I have yet met with, and the inhabitants desert it in the hot weather, taking their camels into Sindh; this custom deprived me of my supply of water camels and obliged me to return earlier than I otherwise should have done.

(17.) In the cold weather, up to the end of December, this portion of the country is alive with flocks and herds which get water from innumerable "tobas" or small tanks excavated in the hard clay, which are as I have already mentioned abundant in Baháwalpur and N.W. Bikanir, and I apprehend no difficulty whatever in taking the series in November through the portion remaining from which I had to retreat this season.

(18.) All the villages have large numbers of camels which roam in the desert and return every few days to the wells to drink, when such as are wanted are caught.

(19.) Nearly all the country I worked through belonged to three influential Thákurs, Bikampur and Birsilpur in Jaisalmir and the Rao of Pugal in Bikanir, which last belongs to one of the oldest Bhatti Rájput families and is reported to have held Pugal for more than 1,000 years.

The villages in which they live are larger, but quite as wretched in appearance as any I met with, the only distinction being that the Thákurs live in a sort of a half house, half fort built of mud and stones.

(20.) The cold was very great at times, the minimum thermometer twice registered 16°; this was very trying to the men who however enjoyed good health as a rule. My experience of the desert is that it is very healthy for people who are well fed and have good water to drink.

Bikanir.

(21.) The city of Bikanir to which a minor series was taken this season to fix its height, is a fine city built on a slightly elevated spot in the desert where the ground is hard and stony and intersected by ravines. It has a wall 3½ miles in circuit, wholly built of stone and in good repair, it has 8 gates and three sally-ports; the wall is from 15 to 30 feet high and it has a ditch on three sides about 15 feet deep. There are many highly carved houses in the city and two imposing looking Jain temples. Water is plentiful from many very fine wells. The chief productions are sugar-candy and blankets, both of which are of a very superior kind. The population is about 35,000.

(22.) The fort of Bikanir which contains the Maharajah's palace is about 300 yards N.E. of the city. The palace rises above the battlements and gives it an imposing appearance: it is 1,100 yards in circumference and has two gates, numerous bastions and a ditch all round.

(23.) The Governments of Marwar, Jaisalmir, Bikanir and Baháwalpur sent officials and men to accompany the camps, in their respective States, and rendered every assistance in their power, and very greatly was their assistance needed, for without it the work could not have been carried on for a day as the water for the camps, had to be brought on an average, 10 to 20 miles on camels.

My best thanks are due to the Political Agents Colonel Minchin, Major Walter and Captain Burton.

Extract from the Narrative Report—dated 8th September 1875—of Captain A. PULLAN, S.C., Officiating Deputy Superintendent 3rd Grade, in charge Kattywar Survey Party.

PERSONNEL.

Captain A. Pullan, S. C.,
John McGill, Esq., Asst. Supdt.

Surveyors and Asst. Surveyors.

Mr. J. Peyton.
" F. Bell.
" N. C. Gwynne.
" E. Wyatt.
" W. A. Fielding.
" W. Oldham.
" G. T. Hall.
" H. Corkery.

Head Sub-Surveyor.

Mr. Visaji Ragunath.

Sub-Surveyors.

Govindji Mahalay.
Narsu Dinkar.
Krishna Govind.
Shridhar Succaram.
Vishnu Moreshwar.
Bholaji Bhoseker.
Nilkant Vital.
Keshu Vital.
Tukaram Chowdry.
Ganesh Ramchandra.
Vishnu Bulwant.

Out-turn of Field work.

The out-turn of field work for the season 1874-75 was not so large as in the two preceding seasons. A considerable portion of the country under review, lying as it does along the borders of the Gulf of Cutch, was very difficult and tedious to survey, not only on account of the treacherous mud banks and almost impassable mangrove swamps, but also from the variable winds and sudden changes of tide among the creeks which threw constant hindrance in the way of the surveyors.

An area of 1877 square miles inclusive of overlaps, or 1749 square miles within graticule, was topographically surveyed, consisting of parts of Prânts Hállár and Machhu Kánthá in Kattywar and a portion of the southern seaboard of Cutch, which was surveyed in order to render the Sheets of Kattywar more complete and to delineate more clearly the head of the Gulf of Cutch. 2200 square miles were trigonometrically surveyed, 200 for the survey of the Cutch coast during the same season, and 2000 in advance preparatory to ensuing topographical operations, and 1117 linear miles of traverse were carried over the area of country topographically surveyed, demarcating the boundaries of States and checking the details of the Plane Table Survey.

It must be borne in mind that the out-turn of work for the two preceding seasons was exceptionally large owing to the wide area of flat 'Rann' it included, and such an out-turn can hardly be expected in future. I may here state that the agreement between our survey of the head of the Gulf and the coast line given by the Marine Survey of Lieutenant Taylor, I. N., is decidedly satisfactory, taking into consideration the difference of scale and mode of delineating ground.

At Rájkot, hearing from Mr. Bell, who was triangulating the seaboard of Cutch, that the nature of the ground on Sathsaida Bet rendered a stone or masonry pillar unadvisable, I devised a pillar composed of piles of hard teak seven feet long, four feet below the surface and three above, arranged in a circular form, the mark-stone being imbedded in the mud beaten hard all round with small pebbles and straw to bind it, and the cylinder being then filled up with shingle from the beach mixed with mud. This pillar is calculated to stand the wash of the monsoon waters better than a masonry pillar, which would offer unyielding resistance and tilt over from its own weight, whereas in the case of the pillars now erected the force of the water is dissipated, and I think they will all be found next season, *in statu quo*.

On arrival at Jámnagar or Nawánagar, the capital of the territories of H. H. the Jám, I found that the border of the Gulf, studded as it is with numerous small islands, intersected by tidal creeks, offered a very difficult piece of work for the Plane Tabler, not only on account of the heavy mud and quicksand, but also from the fact that the work had to be done by boat principally, and the surveyor would have to study carefully the state of the tide and the direction of the wind. This work I took up myself and completed all the northern and difficult portion of the board by the time that it became necessary to cross over to Cutch and examine the Plane Table work on that coast and also about Hanstal Creek. I therefore started on the 26th February for Hanstal *viâ* Juria.

On arriving at Hanstal, I found Mr. Hall getting on very well and surveying the swamps with correctness and facility. I passed on, after examining Mr. Hall's Plane Table, to the opposite coast of Cutch and spent four days in a careful examination of Govindji Mahalay's Plane Table which I found correct and neatly executed. I then returned to Juria and marched along the coast to Balacheri in order to judge for myself of the general character of the coast line and swamps; the journey was a fatiguing and dangerous one and I was very nearly swamped in a quicksand from which I was with difficulty extricated by my khlassies.

I marched from Molila on the 6th April *en route* for Gogo. The heat was at this time intense, far

greater than I had hitherto experienced in Kattywar, and the hot season threatened to be exceptionally severe, I therefore reluctantly gave up the plan of completing Sheet 45 which would have kept the Plane Table parties out until near the end of May, and sent orders to the surveyors and sub-surveyors to the effect that when they had completed the boards they were working they were to march and join me at Gogo and from that port make arrangements for return to recess quarters.

After receiving all the Plane Tables and comparing their borders before taking them to Poona, I started from Gogo on the 12th May and opened office at Poona on the 17th May 1875.

J. McGill, Esq. Asst. Supdt.

Mr. McGill left Wadhwán on the 21st November 1874 to take up and complete the triangulation of Sheet 10a of Kattywar which had been left unfinished by Mr. Wyatt. After completing this work Mr. McGill marched *vid* Malia and the borders of the Rann and examined the southern Plane Tables of Sheet 31. Mr. McGill proceeded thence *vid* Rájkot to Gondal where he commenced the triangulation of Sheets 36 and 37—these Sheets were completed on the 6th April and Mr. McGill marched to Gogo at my request and thence proceeded to Poona.

Mr. McGill worked with the same zeal and ability which has characterized him for many years. His interesting memorandum on Sheet 10a is appended to my report.

Mr. F. Bell, Surveyor 3rd Grade.

Mr. Bell left recess quarters in advance of the rest of the party as I required him to furnish some few extra points on the seaboard of Cutch. Proceeding by boat to the port of Mandir, Mr. Bell commenced work on the 15th November at Charakla H. S., and worked very hard and well; having completed his triangulation he joined my camp on the 21st December and we conjointly computed and projected the points on the Plane Tables and made them over to the Plane Table Surveyors. Mr. Bell then proceeded to take up the triangulation of Sheet 38 which he completed by the end of March. His out-turn of work was 800 square miles, and I have every reason to be satisfied with the number and position of the intersected points.

Mr. N. C. Gwynne, Surveyor 4th Grade.

Mr. Gwynne, after completing Fair Sheets 33—35 of Kattywar, took up his first Plane Table on the 15th January 1875. Mr. Gwynne worked throughout the season with the willingness and energy which distinguish him, turning out 125 square miles of very difficult and hilly country in admirable style besides instructing Mr. H. Corkery, Assistant Surveyor and Sub-Surveyor Vishnu Bulwant. Mr. Gwynne's steady application in the drawing office during recess is worthy of particular notice.

Mr. W. A. Fielding, Asst. Surveyor 2nd Grade.

Mr. Fielding started from Wadhwán on the 24th November for Sheet 31. He was accompanied by Messrs. W. Oldham and H. Corkery, Assistant Surveyors, Sub-Surveyors Nilkant Vital and Ganesh Rámchandra and Traverse Surveyor Tukaram Chowdry. The whole of the Plane Table parties and Traverse party I placed under the orders and general superintendence of Mr. Fielding of whose intelligence and carefulness I had formed a high opinion and I was well satisfied with the result. Mr. Fielding having completed Sheet 31 marched southwards and took up R. Plane Table, S.W. Section of sheet 43. Mr. Fielding's out-turn of work was 154 square miles, very creditable when it is taken into consideration that in Sheet 31 he had to superintend the work of 2 European and 3 Native Assistants besides doing some Plane Table surveying himself.

Mr. W. Oldham, Asst. Surveyor 3rd Grade.

Mr. Oldham worked well throughout the season, first under Mr. Fielding's superintendence in Sheet 31 and afterwards on Sheets 43 and 45 under my own eye. I found Mr. Oldham's work very carefully done on every occasion that I examined it. He requires further practice in neat drawing and printing, and when these are acquired satisfactorily, he will be a valuable Plane Table Surveyor. His out-turn of work 200 square miles for this, his first season, is most creditable to him.

Mr. G. Hall, Asst. Surveyor 3rd Grade.

Mr. Hall worked very well throughout the season both on the borders of the Gulf of Cutch and also in hilly ground in Sheet 44. His out-turn of work was 180 square miles, and I have every reason to be satisfied with its quality.

Mr. H. Corkery, Asst. Surveyor 4th Grade.

Mr. Corkery was employed throughout the season in topographical work; his out-turn was 144 square miles, and both Plane Tables in execution and delineation of hilly country are very creditable to a young hand and show a marked improvement.

Mr. Visaji Ragunath was employed during the major part of the season in projecting Plane Tables, computing Lats., Longs. of intersected points, and in general miscellaneous work; at the beginning of April, I sent him to run a Check Traverse across the Cutch portion of Sheet 31. This work he satisfactorily completed.

Mr. Visaji Ragunath, Head Sub-Surveyor.

Govindji Mahalay executed the Plane Table survey of 171 square miles of country in his usual careful and artistic style. He has also been very useful as a draughtsman during the recess season. Narsu Dinkar was employed in running boundary traverses and check lines during the whole season. He executed in a satisfactory manner 323 linear miles of traverse, and is a useful and hardworking assistant. Krishna Govind was employed during the season as recorder to Mr. Bell. Shridhar Succaram executed 167 square miles of Plane Table survey slowly but accurately.

Vishnu Moreshwar worked very steadily throughout the field season. His out-turn was 196 square miles, and there was some improvement this season in his delineation of hilly ground. Bholaji Bhosekar was employed throughout the season in boundary traversing and running check lines; he completed 273 linear miles of traverse. In consequence of information received from you respecting the amount to be expended on the Native Establishment of this party, I was obliged to reduce two parties, one Plane Table and one Traverse party; Bholaji Bhosekar being the least useful of the Traverse Surveyors was therefore discharged. Nilkant Vital executed 164 square miles of topography with accuracy and some improvement in his style of drawing. Keshu Vital executed 146 square miles of topography; there is much room for improvement in his style of sketching ground. He is a good computer. Ganesh Rámchandra executed 170 square miles of topography in a very creditable way for so young a hand. Vishnu Bulwant is very useful in the drawing office and promises in time to be a really good draughtsman.

The principal towns contained in the country now under consideration are; 1st, Jámnagar or Nawánagar, the capital of the territories of the Jám of Nawánagar which district comprises, roughly speaking, with the exception of a few small detached holdings, Sheets 42, 43, 44, 45 and the eastern halves of 52 and 53. The town which is on the banks of the little river Nágmati is clean and well built with good streets. The population according to the last census amounts to 34,744 souls. The Jám, a Jhareja Rájput, is gentlemanly and pleasant and from either liking or policy affects the society of Europeans, treating all who visit his territories with much courtesy and hospitality.

Principal Towns, &c.

The other towns of note in the Jám's territories are Hariana, Dhunwao and Balamba. The last named town is supplied with good water by means of a canal four miles long which carries the sweet waters of the Aji up to the town; tradition has it that a rich Brahmin of Balamba was enamoured of the daughter of a Brahmin of Latipur; but as Balamba was notorious for its bad brackish water, the girl's father refused his consent until his daughter was sure of good water to drink in her new home. The suitor thereupon set to work and had the canal cut which now exists thereby winning his bride. A dam is now in course of construction near the village of Madhapur on the Aji which will, when completed, render the canal always full of sweet fresh water.

The town of Malia, on the banks of the Machhu was 50 years ago a very strong place; it is the only place of importance in Sheet 31: the inhabitants are principally "Miani" Mahomedans, but the Rája is a Jhareja Rájput of the Cutch family.

Near Jámnagar is a little pleasure house and temple called Rozi Mata, a favorite summer resort of the Jám's, situated on a small island or rather isthmus which juts out into the lagoons and swamps of the Gulf; the fresh breezes from the sea render Rozi a pleasant place of sojourn during the hot months; the island is covered with long grass and tangled thicket giving cover to herds of "Nylghai" or "Roz" which roam at will unmolested, the island as its name implies being their favorite haunt. Near the small village of Balacheri there is a bungalow on the shore of the Gulf built by the Jám and occupied during the hot months by the political officers; at a short distance from the bungalow is the village of Sachana, the inhabitants of which drive a thriving trade in fish of various kinds, and send a regular supply to the British Station of Rájkot.

The Machhu river flowing into the Rann of Cutch at Malia and losing itself in the salt sand and mud of the Gulf, is the principal drainage line in the country surveyed this season. The others are the Nágmati which rises in the hilly country 30 miles south of Jámnagar, the Aji the head of which only enters these sheets where it debouches 3 miles north of Hanstal tidal station into the Hanstal Creek, the Nani and Moti Phuljar, the Und and the Manwar.

Rivers.

Sheet 31 calls for no further particular description as what I said in my Narrative Report for season 1873-74 of Sheet 32 will apply equally to the country in Sheet 31. Sheets 42 and 43 are flat and well cultivated up to the very edge of the mangrove swamps which are a leading feature of the country and which spread along the Gulf in a broad belt from Hanstal and even higher than that, southward over all the coast surveyed last season, near the town of Jámnagar all the islands and spits of thick rich mud are covered with tangled mangrove jungle in some places rising to an altitude of 40 feet but generally averaging from 8 to 10 feet in height. At high tide a little fleet of boats puts out from Beri Bunder carrying the wood cutters to their work in the lagoons, the white sails gleam on all sides among the masses of rich green foliage and the labourers cut and stack mangrove till a returning tide bears them homeward; the stock of firewood thus obtained is a godsend to Jámnagar as the supply of wood round the city is scanty, a large quantity is also laid in by the Bombay bound craft that put in at the little port of Beri.

General appearance of the country.

The country in Sheet 44 is undulating, crossed here and there by low ridges—a stony and sterile land poorly cultivated; there are few villages of any size in Sheet 44 except on its eastern border where the country is somewhat less stony and the soil richer and better cultivated.

Throughout the low ranges which cross Sheets 43 and 44 are numerous stone quarries, where a coarse white sandstone is excavated; this stone though porous and friable when first brought to the surface, hardens greatly by exposure to rain and sun and becomes a useful building stone.

Quarries.

To meet the wishes of the Political Agent, I propose next season to triangulate Sheets 46, 47 and 48 in advance, and to survey topographically Sheets 36, 37 and 38 and the portion of Sheet 45 which still remains unfinished—the small portion of coast near Diu of which Sheet 41 consists, I shall also, I think, be able to complete as the triangulation has been done and nothing remains but the boundary traverses and topographical detail Survey.

TABULAR STATEMENT OF OUT-TURN OF WORK IN KATTYWAR DURING THE FIELD SEASON 1874-75.

Triangulation.

No.	Observers' Names.	Instruments used.	Area triangulated in square miles.	No. of Points Heights fixed.	No. of Points Position fixed.	No. of stations visited.	Triangles, 3 Angles observed.			Triangles, 2 Angles observed.	
							No. of triangles.	Mean triangular Error.	Discrepancy per mile.	No. of triangles.	Average discrepancy per mile.
								"	Feet		Feet
1	John McGill, Esq.,...	Cooke and Son's 7-Inch	1400	253	595	80	135	10·2	0·8	950	1·3
2	Mr. F. Bell, ...	Troughton and Simms' 6-Inch	800	69	206	55	76	9·3	0·5	428	0·8
		Totals, ...	2200	322	801	135	211	Mean 9·8	Mean 0·7	1378	Mean 1·1

Topography.

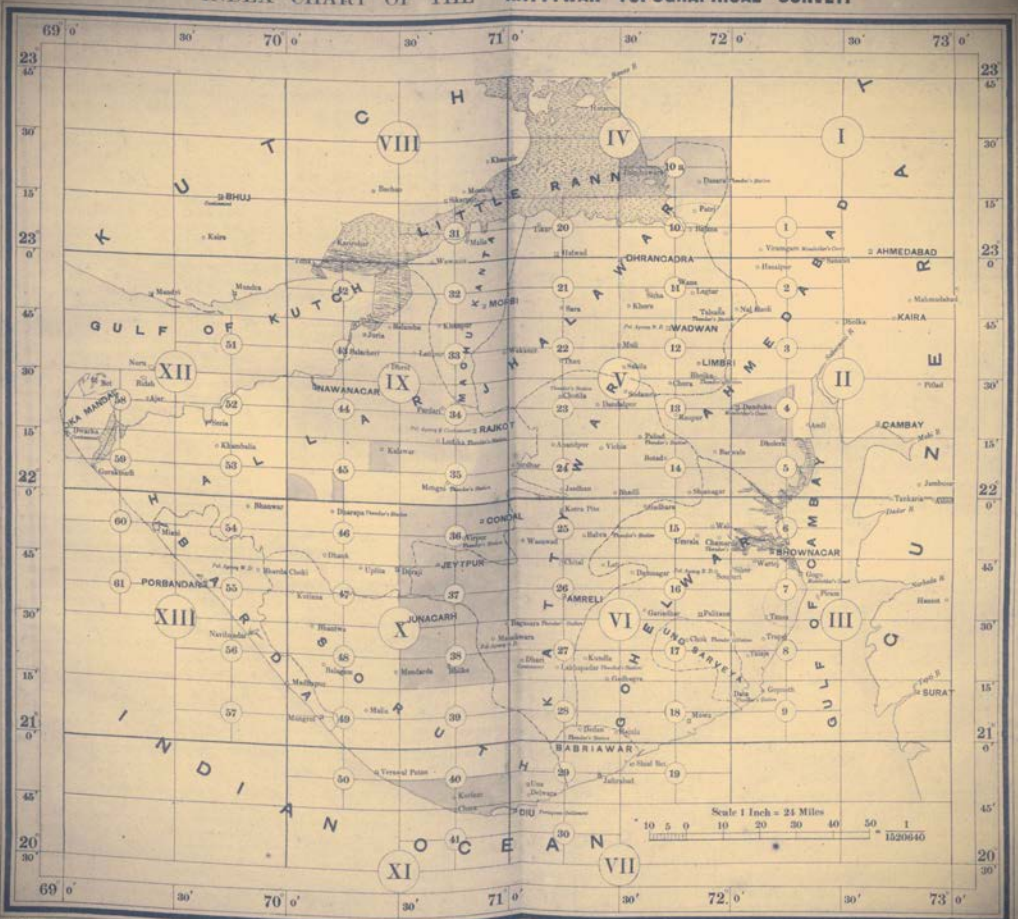
No.	Plane-tabling.	Area surveyed Scale 2 inches = 1 mile.	Average No. of plane table stations per square mile.	Remarks.
1	Captain A. Pullan, s.c. ...	30	5·8	
2	Mr. N. C. Gwynne, ...	125	7·3	
3	„ W. A. Fielding, ...	154	8·9	
4	„ W. Oldham, ...	200	12·8	
5	„ G. T. Hall, ...	180	5·5	
6	„ H. Corkery, ...	144	12·5	
	Native Surveyors.			
7	Govindji Mahalay, ...	171	6·0	
8	Shridhar Succaram, ...	167	9·0	
9	Vishnu Moreshwar, ...	196	12·7	
10	Keshu Vital, ...	146	10·0	
11	Nilkant Vital, ...	164	12·6	
12	Ganesh Rámchandra,... ...	170	12·4	
13	Vishnu Bulwant, ...	80	7·5	
	Total number of square miles surveyed inclusive of overlap ...	1877	...	

Traverses.

Names.	No. of linear miles traversed.		Average error per 1000 links.	Remarks.
	Taluka Boundary.	Check Line.		
Mr. Visaji Ragunath, ...	...	21·33		
Narsu Dinkar, ...	160·30	162·56	0·69	
Bholaji Bhosekar, ...	179·94	93·33	0·54	
Tukaram Chowdry, ...	143·78	355·26	0·79	
Totals, ...	484·02	632·48	Mean 0·67	

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

INDEX CHART OF THE KATTYWAR TOPOGRAPHICAL SURVEY.



The numerals 1, 2, 3 &c., indicate the sheets on the scale of one inch to the mile. The numerals I, II, III &c., indicate the degree sheets, on the Scale of ½ inch to the mile.

The nine inch sheets are divided into a sections known as the N.E., N.W., S.E., & S.W., sections of the sheet, of these a few copies will be published on the Scale of the original Survey, viz., 2 inches to the mile for the use of local officials.

Districts remaining Topographically Surveyed up to 1874-75

Ditto Triangulated in advance up to 1874-75

Photozincographed at the Office of the Superintendent, Great Trigonometrical Survey, Dehra Dún, November 1875.

Extract from the Narrative Report—dated 15th October 1875—of Major C. T. HAIG, R.E., Deputy Superintendent 2nd Grade, in charge of the Guzerat Survey Party.

PERSONNEL.

Major C. T. Haig, R.E.
Lieutenant J. E. Gibbs, R.E.
Mr. J. Peyton.
" A. D'Souza.
" A. D. L. Christie.
" C. H. McAFee.
" E. J. Connor.
" J. Hickie.
" G. D. Casson.
" G. Hall.
" S. Norman.
" C. Norman.

Native Surveyors.

Gopal Vishnu.
Luximon Gorpuray.
Ganesh Narayen.
Ganesh Bapuji 1st.
Raoji Narayen.
Mukand Dinkar.
Ganesh Bapuji 2nd.
Bhow Govind.
Govind Gopal.
Bulwant Rajaram.
Monaji Aboo.

Revenue Survey.

Mr. T. A. LeMesurier.

Native Surveyors.

Keshowram Ravishanker.
Jugal Mansukram.
Dowlat Lalbhai.
Gopal Ganesh.
Kuber Parbhudass.
Parbhu Kisor.
Trimbaklal Govardhan.

(3.) During the season an area of 1375 square miles was topographed: of this 983 square miles was on the scale of 4 inches to a mile and 392 square miles on the 2-inch scale. In the Dang Forests an area of about 550 square miles was triangulated, but this will have to be supplemented with further triangulation and traversing to furnish a sufficiency of data points for the final Survey. A small area in sheet 79, which remained incomplete at the close of the previous season, was completed with data points, by traversing; and an area of about 300 square miles of British territory previously triangulated was prepared for Survey on the 4-inch scale, by effecting the necessary connections between the fiscal details of the Revenue Survey and our triangulation stations by means of traversing.

(4.) The area topographically surveyed comprises the whole of sheets 81 and 82 (which completes the topography of Degree Sheet III), and the completion of sheet 14 of which one quarter was surveyed in the previous season; it thus fills up two gaps which last year presented on unsightly appearance on the Index map.

(5.) Sheets 81 and 82 include portion of the Dholka, Viramgám, and Dhandhuka talukas of the Ahmedabad Collectorate and portions of the Limri, Lakhtar, Wadhwán and Cambay states which have now been completely surveyed and sheet 14 includes portion of the Ankleswar taluka of the Broach Collectorate and of the Olpád* taluka of the Surat Collectorate.

(6.) The country in sheets 81 and 82 is very flat and the north-east portion of 81 and south-west portion of 82 are very woody. These sheets include the mouth and about 33 miles of the course of the Sábarmati river and about the same length of the Bhádhar, Bhogáwo and Rodh rivers, and also the water connection during the monsoon between the Nal and the Gulf of Cambay which I mentioned in para. 16 of my last year's report as probably existing. It is now established that during the monsoon the Peninsula of Kattywar becomes an island. Sheet 81 also includes a portion of the Nal lake, the greater portion of which is included in sheet 80, and was mentioned in my last year's report. When I wrote that report I thought the portion left in sheet 81 was so small that I spoke of sheet 80 containing the whole lake, but it appears that the extents of the lake in November varies very considerably from its extent in March. Many square miles which are dry in March and become the haunts of wild boar and wolves, are in November several feet under water. I would remark generally that the drainage of Guzerat is, from the flatness of the country, very capricious; some of the rivers lose themselves in marsh or in sand, resolving themselves into streams again further on, in their passage to the sea; others change their course in a perplexing way, and none of them have a sufficiently rapid fall to carry off at once any extraordinary rain fall, and so every year the towns on their banks and the bridges are in danger. The Sábarmati, which has lately overflowed its banks and done such damage to the city of Ahmedabad and to many villages on its banks—for the second time within the last few years—is also remarkable for the capricious way in which it alters its course. I have the Revenue Survey map of a village (Rinjha) dated 1856 on which an alteration in the fiscal details was made in 1867 owing to a change in the course of the Sábarmati, the left bank shifting $\frac{3}{8}$ and the right $\frac{5}{8}$ of a mile, the new left bank being $\frac{3}{16}$ of a mile to the right of the old right bank, and our Survey this year shews a still further divergence from the old course. To give another instance, it will be found in the correspondence of the Bombay Party that in 1855 a stage erected at a place called Sikutar Mátha for taking tidal observations, was washed clean away by the force of the current, the site of that stage is now half a mile inland and is only flooded at spring tides.

(7.) Sheets 81 and 82 are crossed by the Ahmedabad and Gogo road, but it scarcely deserves mention as in nearly the whole of its extent across these sheets it is out of repair, and in some places

* In last year's report para. 22, I gave three different ways in which this town is spelt, Olpád is now a fourth, but is that recently adopted and established by the Government of Bombay in the official list of names.

totally obliterated. Dhandhuka the chief town of one of the talukas of the Ahmedabad Collectorate is on this road and is about halfway between Ahmedabad and Gogo. It is in sheet 82. Dholka another taluka town and next to Ahmedabad the most important in the Collectorate, is in sheet 81. On account of the importance of Dholka I had all the principal thoroughfares traversed with a prismatic compass and chain so that the town could if necessary be mapped on a larger scale than that of 4 inches to a mile; but on this scale it is a most imposing feature in the map, being nearly 6 inches from north to south and 3 inches from east to west. The Thákur's towns of Koth and Gángad are also in this sheet, and Dholera (well known in connection with cotton) is in sheet 82. Sheet 81 contains a large area of Talukdari land interspersed with the Khálsa (I explained the meaning of these terms in para. 20 of my last year's report) but in sheet 82 the two classes of tenure are more separate, and I was therefore enabled to survey an area of 392 square miles of Talukdari land in that sheet on the 2-inch scale.

(8.) The country in sheet 14 is flat, and fairly wooded with babool and palm trees, though along the coast there is a considerable expanse of sand and mud which, on account of the number of intersecting creeks and nalas, required as much labour in surveying as cultivated land and even more, because of the difficulty of moving over the ground. The Kim and Sona rivers cross Sheet 14 from east to west. They are neither of much importance, not being navigable for large craft, but the Kim is the larger of the two; both have considerable estuaries, increasing the expanse of mud. The villages in this sheet are much more closely packed than in sheets 81 and 82: in the portion surveyed this season these are none of any great importance though all are fairly populous. Perhaps Elão in the Ankleśar taluka and Bagwa and Kursad in the Olpád taluka are the most so.

(9.) Leaving Poona on the 11th November we commenced work in sheet 81 on the 21st. Having a sufficiency of ground triangulated in advance for two years, I gave Plane Tables to both Mr. Christie and Mr. Connor who had previously always worked with a theodolite. The two Messrs. Normann and three Native Surveyors having but recently joined the Department in September and October, had also to learn the use of the Plane Table. I could not commence the instruction of all these pupils at once, and therefore I employed those who had to wait, in my Office, where there was always plenty of miscellaneous work to be done in connection with the mapping.

(10.) One new feature in the administration of my Party was the formation of a permanent Drawing Office. I found this absolutely necessary, because my mapping power had been most severely overtaxed by the great amount of mapping thrown upon it by the adoption of the 4-inch scale and I therefore kept Mr. Peyton and six Native Surveyors at my Head Quarter Camp and I supplemented this force at the beginning of the season by those hands who were waiting to be taught Plane Tabling. The Revenue Survey Surveyors were employed solely in plotting the traverses on the Plane Table Sections, as they came in, as checks to test their accuracy, and in transferring on to them the fiscal details from Revenue Survey village maps.

(11.) On leaving Ahmedabad I apportioned off the work to the different Surveyors, and took my Head Quarter Camp to a central position in their midst from which I could run out and see them each at work: I was disappointed at the rate at which the Survey of sheet 81 progressed, some of the talukdari villages interlaced with the Khálsa gave a great deal of trouble from the fiscal demarcations being obliterated, and from the patches of cultivation along the margins of the marshy connection between the Nal and the Bhádhar river not conforming to the field partition shown on the village maps. All these patches were surveyed, but at the cost of a great deal of time. On the completion of sheets 81 and 82 we moved into sheet 14, which was completed by 15th May, and I myself opened Office in Poona on 20th April.

Lieutenant Gibbs, R.E.

(12.) During the early portion of the season, that is till the end of January, Lieutenant Gibbs was engaged in Plane Tabling, and he completed two Plane Tables in sheet 81 on the 4-inch scale, comprising 36 square miles. After this I sent him to examine the Plane Table containing the town of Dholka and then to continue the triangulation of the Dangs, which he commenced in the previous season.

(16.) He succeeded in fixing a great number of points, but found it impossible to fix any down in the ravines, on account of their being so tortuous and precipitous; it will therefore be necessary to supplement his operations with traverses running along the ravines, in order to give data points to the Plane Tablers who will be obliged to work either on the tops of the hills, or the bottoms of the valleys, and sketch in the precipices, and when in a ravine they would never be able to see the stations on the heights.

(17.) Lieutenant Gibbs had a very difficult task, as may easily be imagined from the fact that the whole of the country in the Dangs is mountainous and wooded and intersected with precipitous, tortuous ravines, and that his stations vary in height capriciously between 1500 and 5000 feet.

Mr. Peyton.

(18.) I kept Mr. Peyton during the whole field season at my Head Quarter Camp as the head of the Drawing Office, the strength and duties of which I have mentioned in para. 10.

Mr. D'Souza.

(19,) Mr. D'Souza supervised all the Native Surveyors' Plane Tabling on the 4-inch scale, and instructed as well as supervised Messrs. Christie, S. Norman and C. Norman (partly instructed also by Mr. McAFee) and Gopal Vishnu, Govind Gopal, and Bulwant Rajaram, so that he was actively employed the whole season, as he altogether examined 41 Plane Tables on the 4-inch scale, and 1 Plane Table on the 2-inch scale, comprising an area of 736 square miles.

Mr. Christie.

(20.) Mr. Christie was employed the whole season in Plane Tabling on the 4-inch scale, and considering that it was his first season at that work, his out-turn is very creditable, both as to quantity and quality. Mr. Christie is also very observant of the country he surveys, and has given me a report describing fully each Plane Table that he completed.

Mr. McAFee.

(21.) Mr. McAFee joined me on the 31st December and I kept him at the Head Quarter Office till the 5th February, when I gave him a Plane Table in sheet 81 on the 4-inch scale, and sent Mr. C. Norman with him for instruction. After starting Mr. C. Norman he was employed for the remainder of the season on the topography on the 2-inch scale in sheet 82, and had working under him Ganesh Bapuji 1st and Raoji Narayon; he is a very careful and accurate worker.

Mr. Connor.

(22.) Mr. Connor, though he had learnt how to use a Plane Table before in the Kattywar Party, had never learnt how to utilize the Revenue Survey materials, Mr. D'Souza therefore gave him a helping hand at first, and then he soon went on with his Plane Table independently, but owing to his eyes failing him, not being strong enough to stand the continual glare, I had to find other work for him at my Head Quarters, in projecting the Plane Tables and other miscellaneous duties.

Mr. Hickie.

(23.) Mr. Hickie was employed the whole season through in Plane Tabling, first in sheet 81 where he completed 3 Plane Tables on the 4-inch scale, then a Plane Table in sheet 82 on the 2-inch scale, and then 2 Plane Tables in sheet 14 on the 4-inch scale. He is a careful and accurate worker.

Mr. Cusson.

(24.) Mr. Cusson was also employed the whole season in Plane Tabling, first in sheet 81 where he completed 3 Plane Tables, one of which included the large town of Dholka, which he surveyed very accurately and mapped very neatly. He then completed a Plane Table in sheet 82 on the 2-inch scale, and then 2 Plane Tables in sheet 14 on the 4-inch scale. He is a very neat draftsman.

Mr. Hall.

(25.) Mr. Hall after completing one Plane Table in sheet 81 on the 4-inch scale was transferred to the Kattywar Party.

Mr. S. Norman.

(26.) Mr. S. Norman was only appointed to the Department on 1st September, so he had every thing to learn. He rapidly acquired a knowledge of Plane Tabling, and during the season completed an out-turn of 94 square miles on the 4-inch scale very accurately and neatly.

Mr. C. Norman.

(27.) Mr. C. Norman only joined the Department on the 12th October, so like his brother had every thing to learn. His out-turn was only 59 square miles on the 4-inch scale, but he was employed in my Office projecting Plane Tables and on other miscellaneous work until the 8th February. He too promises well for duties both in the field and in office.

Native Surveyors.

(28). Mr. D'Souza reports well of all the Native Surveyors working under him. Gopal Vishnu who had hitherto been employed as a Traverse Surveyor, has turned out a very fair Plane Tabler. The two new hands Govind Gopal and Bulwant Rajaram both promise well.

Revenue Survey.

(29.) The Native Surveyors of the Revenue Survey Party were divided between two duties. Mr. T. A. Le Mesurier, the Assistant Superintendent, in charge with 3 Native Surveyors were employed traversing in sheets 31, 32, connecting the village boundary trijunctions and village sites of the British territory with the triangulation, while 4 Native Surveyors were employed in my Office transferring the fiscal details from the Revenue Survey village maps to our Plane Tables as they came in.

(30.) It will perhaps be noticed that in my last year's report I only mentioned the Revenue Survey Party as consisting of 5 Native Surveyors, whereas in this report there are 7. Each season I have to consider the proportion of Native Surveyors to underlings that I require, and the Superintendent of the Guzerat Revenue Survey supplies me either with more Native Surveyors and less funds to

pay for underlings, or *vice versâ;* the total salaries of both being limited to Rupees 500 a month. During the past season I only required very little more ground to be prepared in advance of the topography, but that the drawing power was insufficient to meet my requirements. I therefore drew on the Superintendent Revenue Survey for 2 more Native Surveyors for employment in my Office.

Mapping.

(34.) I beg to inform you that, when we take the field at the end of this month, I expect that with the exception of part of the inking in of the fields on 4 sections, the whole of the *drawing* of the sections on the 4-inch scale will be completed, but there will remain a quantity of printing work on several sections, which will be carried on by the permanent Drawing Office that I shall take into the field. The drawing of the sections on the 2-inch scale has also been commenced, but will have to be finished in the field. I expect to have all the sections now in hand completed before we return to recess quarters.

(35.) I am happy to inform you that there is a marked improvement in the mapping of this recess over that of last year. Last year we worked under great disadvantages, but we learnt several lessons, which have been turned to account this year, and now the hands are classified into (1) free hand draftsmen, (2) second class draftsmen and (3) mechanical draftsmen, and the printers are also divided into (1) hand printers, (2) and (3) 1st and 2nd class type printers. To each section, before it is begun, is stitched a printed form called "Section Register" in which all the different stages through which the map has to pass are tabulated, and against each there is a space for the signature of the draftsman or examiner, who passes it through the particular stage, so that each map progresses regularly, and passes from one class of draftsman to another, according as the stages are divided among the different classes. This method could not be arrived at at once, and the want of it last year was the cause of many errors, which have taken up a great deal of time in correcting.

Computations.

(36.) All computations have been completed.

Extracts from Notes on the portion of the Dangs visited by Lieutenant J. E. Gibbs, R.E., in February—May 1875.

(1.) The country in which I have been working this season comprises portions of the Dang Forest, together with some Gaekwar territory, part of the Pimpalner taluka of Khandesh and part of the Báglán taluka of Násik.

(2.) I must preface my remarks with a few words concerning the notes that were published in the General Report for 1873-74. They were in some cases merely records of the impressions with which I was struck at the time, and which I was content to leave as such till I should verify or correct them this year, having no idea that they would go further than the office table. I shall now have occasion to correct some of my statements of last year.

Aspect of the country.

(3.) The whole of the hills forming the Dangs may be looked upon as the first step of the trap formation leading to the Deccan table land. The second step is at the Ghâts bordering the east of the Dangs. The lower step is deeply cut into, as with a graver, by the water courses of the torrents of the rainy season. At the foot of the upper step the valleys rise to nearly the original level of the ground; thus in a direct distance of about 10 miles the water courses have a fall of about 1500 feet. The 'tread' of the lower step, and its valleys are clothed with forest. The upper step is fringed along its western edge by high peaks. The strata are perfectly horizontal and the peaks consist of vertical columns of basalt. Where these are equal in height they give the appearance of a tower, but where of unequal height and arranged like the half of a set of organ pipes, they give at a distance the illusion of *tilting*, which I noted last year, and which I again noticed on leaving the Dangs this year. On the upper step the aspect is quite different. From one of my stations on the peaks of the fringe, which there ran roughly north and south, to the north-east lay a flat plain dotted with low conical hills, bare of trees, to the east and south-east were high hills with flat tops, or peaks, but only clothed below with forest. To the west lay the Dangs, a monotonous expanse of forest. Looking down there scarcely appeared to be any hills, the valleys being too steep-sided and winding to show. Generally speaking the aspect of the country is wild and inhospitable, but occasionally picturesque gorges, and dells may be met with, though always of a wild character.

Hill Forts.

(4.) In the course of my work I visited the hill forts of Rupgarh, Songarh, and Sáler belonging to H. H. the Gaekwar.

Rupgarh Fort was taken from the Bhils by one of the Gaekwars, but has long since been abandoned, and is in ruins. It lies in a very silent position on the frontier, and at one time was useful for keeping the Bhils in check. Last year I made a note of a perennial spring supplying a tank in the fort. Dissatisfied at the time with the information I received that the tank was supplied by a spring, I examined the place, and thought over the matter this year. The level this year in March was within an inch or two the same as in May last year. The tank is at the highest part of the fort, which stands on a mass of rock high above any thing else within miles, so that it could not be a spring of descent. The water is cold, and there is neither motion in it, nor overflow, as would be caused by a spring from a great depth. A syphon could not exist through rocks of so jointed a kind as trap. The only explanation therefore that I can give for the presence of this constant supply is that, as in the case at the ponds made on the South Downs of England, the daily sea breezes laden with vapour reach Rupgarh almost without obstruction, and there, being checked and meeting with the cold surface of the water already there, they are deprived of their vapour, which condenses to collect in the tank.

Songarh Fort is on the hill to the west of the once walled town of Songarh. It was originally seized from the Bhils, some families of whom still hold Jaghirs in connection with it. It has a garrison of 25 men, and there are 35 guns in it, which are rusty and honey combed. The only portion of the defences at all kept in repair is the entrance at the northern end. From the top of the hill two high walls run down splaying out, and are connected at the bottom by a very high wall in which is a gateway. In the lower part of the enclosed space are the ruins of what must have been a fine palace with several stories. Songarh is the Head Quarters of the Pargana.

Sáler Fort stands on an immense mass of basaltic rock on the top of the upper step. This mass of rock is very steeply precipitous on the southern side, where it is slightly concave, the horns of the crescent flanking the ground between. The security of the fort lies in its natural inaccessibility. The ascent is by a zigzag rock-cut staircase up the southern cliff, completely in view from the ridge above, as far as the simple but ingenious system of gate-defences that bar access to a narrow ledge along and halfway up the western face. From the northern end of this ledge is another rock-cut staircase leading to the second set of defences that are just below the level of the spring of the 'roof'. The most active of goats could not ascend by any but the regular path. On the top are cattle and goats that have been carried up when young, a good supply of water in tanks at the foot of the roof-slope (which is about 200 feet high), and rock-cut casemates for the garrison.

Climate and Health.

(5.) I think that the evil reports about the Dangs are exaggerated. Whether this year and the last have been exceptionally healthy or not I do not know, but judging from them I think that with a little care there need be very little danger of sickness between the end of February and the middle or end of May. I believe that during that period there is little or nothing to fear in the air. Without doubt the water is unfit to drink, not only because in many places it is mixed with the rank products of rotting vegetation, but that it is still impregnated with the malaria of the cold season. The sovereign cure for this I believe lies in distilling all water for drinking or cooking purposes. Hindús, who drink water in large quantities, and who will not touch distilled water because stills were unknown to their forefathers, suffer considerably, and I had several very serious cases of remittent fever among the Hindús of my party. The rest all enjoyed very good health.

Inhabitants.

(6.) Last year the statistics I collected about 14 villages that I visited in forest tracts, showed that the percentage of children was 36·55 and this year the statistics of 26 villages gives as the percentage 37·96. On comparison with the Census Report of the Bombay Presidency, I find that the proportion is a little over that for the whole Presidency taken together, and therefore my conclusion last year that the population here was rapidly decreasing may be erroneous, still I believe I was not very wrong, and think that, considering the few old people one sees, the percentage of children is small.

The hillmen generally are very superstitious and their worship being dictated by fear, stones erected to Wághdeo (the tiger god) and Nágdeo (the snake god) are very common.

As I worked more in the heart of the Forest this year than last, I naturally saw more Bhils. They are however disappearing from the country. The Bhil chiefs are 14 in number, 5 being styled Rájá, and the rest Naik.

I visited a manufactory of Káth, the Parsee Overseer showing me every thing. The process was just the same as I described last year. I was amused, if not shocked, by the nonchalance of primitive innocence with which several young women, *habillées peut-être, mais non vêtues*, stood around. Some were absolutely less clad than the men. The dirtiness of the people is rivalled by the dirtiness of the process.

At one village *vidi mirabile monstrum* in the form of a young woman built by nature to be a left-handed amazon. Her right breast was supplying the wants of her baby, but it is fortunate she had not twins.

The Forest.

(7.) While working in and along the boundary of Gaekwar territory, I was surprised to see the wretched state of the trees, especially teak. One might reckon on the core of any teak tree over a foot in diameter being rotten, and the trees were all misshapen. I was agreeably struck by the contrast on working into the Dang States. The superiority in size, symmetry and healthy growth of the trees under the Forest Department over those in the uncared for Gaekwar districts, catches even the untrained eye at once, and speaks volumes in praise of the care and efforts of the Department. The trees are tall, thick and straight, and solid throughout, and the old trees that are felled are replaced by healthy saplings. In some dells the trees were particularly fine with tall straight trunks, not branching till they had attained a great height.

Botany.

(9.) Last year in my notes the trees &c., mentioned were put down irrespective of order, I have therefore repeated their names in the following list of species I have identified. The native names are those given me by the hillmen, who seem to have names for all trees and plants. Besides the following I noticed several that I hope next year to be able to identify.

Capparideæ—Capparis pedunculosa, a small shrub with recurved thorns and umbels of small white flowers having long gynophors.—2500 feet.

Malvaceæ—Hibiscus Rosa Sinensis (Jasodi), the shoe flower in Sáler gardens.

Bombax—Malabaricum (Sáonwar), red silk cotton tree, described last year.—Dang Valleys.

Sterculiaceæ—Sterculia urens (Khandol) described last year.—Dang Valleys.

Tiliaceæ—Grewia abutilifolia (Dhamon), a small tree with 3-nerved leaves and cymes of small yellow flowers, having petals much smaller than sepals; drupes small yellow said to be edible; wood hard and strong.—2000 feet.

Rutaceæ.—Ægle Marmelos (Bil) with 3-foliolate leaves (emblematic of the Hindú Trinity), and large globose fruit having a woody rind and many seeds in a sweet aromatic orange pulp, valuable in dysentery.—1500 feet.

Anacardiaceæ.—Mangifera Indica (Am), the common mango, near village sites.

Celastrineæ.—Celastrus paniculata (Kárkángun), a scandent shrub with pendulous panicles of tiny greenish flowers; the seeds yield lamp-oil.—Dang Valleys.

Rhamneæ.—Zizyphus rugosa (Turan), a small tree with recurved prickles; fleshy white fruit with crustaceous stone, having a mawkish taste, and being much eaten by the inhabitants.—Common even over 3000 feet (See Hooker's Flora of India).

Rhamnus Wightii (Ragatrura), a small shrub with shortly accuminate fascicled leaves; panicles starting opposite to one of the lowest leaves of a tuft; berries, $\frac{2}{3}$ size of a pea, superior, 4-seeded, red-orange; calyx persistent—evidently rare as I only saw one specimen, and few of the villagers knew its name.

Leguminosæ—Erythrina Indica (Pangara), a tree armed with black prickles; leaves 3-foliolate; racemes of bright scarlet flowers in March. Wood used for sword sheaths (Bird-wood).—Dang Valleys.

Erythrina suberosa (also called Pangara), very similar to the above but with cork like bark.—Dang Valleys.

Butea frondosa (Palas Kankara), known to Europeans as the Dák, a shrub with 3-foliolate, leaves leaflets large, used as plates or drinking cups; tomentose racemes of large silky orange-red flowers in February and March; legumes downy, one seeded.—Everywhere.

Pongamia glabra (Kurunj), a tree with 5—7-foliolate leaves with large glabrous leaflets; axillary racemes of shortly pedicelled pink and white papilionaceous flowers.—Dang Valleys.

Dalbergia latifolia (the Sisu of the Bombay Presidency), the black-wood tree.—1500 feet.

Dalbergia ougeinensis (Tanaj), a large tree with 3-foliolate leaves, leaflets large, reddish when young; racemes of small pink flowers; wood tough, strong, and heavy.—Up to 1500 feet.

Cassia fistula (Báwa), a small tree with *pinnate leaves having 5 pairs of leaflets*; pendulous racemes of bright yellow flowers; pods long, cylindrical, divided by spurious traverse plates into one-seeded cells; seeds hard, shiny, collected by red beetles.—Everywhere.

Tamarindus Indica (Amli or Chinch), near village sites.

Bauhinia Racemosa (Aapta), a small tree or shrub; leaves used when dry for making 'biris' or native cigarettes; terminal racemes of small white flowers.—Common everywhere.

Acacia Catechu (Khair) mentioned last year.—Common everywhere.

Albizzia Lebbek (Siris), a large tree with black bark, and dark heart-wood somewhat like black-wood; leaves abruptly bipinnate; pinnæ 2—6 pairs; leaflets 10—15 pairs, very oblique; raceme axillary, long peduncled with many close 10—15 flowered heads.—Up to 1500 feet.

Cicer Arietinum (Chana), gram cultivated about Songarh.

Phaseolus Mungo (Urid) cultivated in small patches in the Dangs.

Combretaceæ.—Anogeissus Latifolius (Dáora), a tree with white bark and wood, and light green elliptical leaves; it yields a very fine strong white gum.—In valleys and up to 1500 feet.

Terminalia Chebula (Herdi), leaves large, oblong and downy when young; petioles short with pair of glands at apex; panicles of purple oval drupes having a bloom; drupes (myrobolans) valuable for their tannin.—2500 feet.

Terminalia Arjuna (Mota Sádra), a large tree with smooth bark and dark heart-wood.—Up to 1500 feet.

Myrtaceæ.—Sizygium Jambolanum (Jámbul), a tree with light colored bark and opposite, entire shining leaves; 3-forked panicles of small white flowers with calyptrate corolla; good timber and edible fruit.—Near village sites.

Sizygium Salicifolium (Jámbul), a shrub with willow-shaped leaves; lax panicles of small white flowers.—In beds of rivers.

Careya arborea (Kumbi), a tree with large entire membraneous leaves, much eaten by a small white caterpillar; leaves after flowers; flowers with 2—3 hundred long white stamens; style long, honey at base; fruit the size of a small apple, edible.—2000 feet.

Cucurbitaceæ.—Cucumis trigonus with oval fruit, yellow striped with green, very bitter; climbing or creeping about shrubs.—2000 feet.

Loranthaceæ.—Loranthus bicolar (Bhendgol), a very common parasite especially on the Aapta; flowers long, slender, scarlet and green; leaves opposite, entire; disc accrescent round inferior ovary.—Everywhere.

Rubiaceæ.—Nauclea cordifolia (Hedu), a large tree with roundish downy stipulate leaves, and round heads of flowers.—Valleys.

Gardenia dumetorum (Gál), a small spinous tree with opposite, simple entire leaves having interpetiolar stipules; flowers sessile, axillary, solitary, white fading to yellow; fruit round.—Everywhere.

Gardenia lucida ? (Tendrum), very similar to the above but with large flowers; flowers full of honey; stigma large, brown and sticky.—Everywhere.

Compositæ.—Blumea holoserica, a small downy herb with deeply serrate leaves, and yellow flower-heads in elongated panicles. So common all over disused clearings, that at first I thought it must be cultivated.

Oleaceæ.—Jasminum Sambac (Bhat Mogra), a shrub with fragrant, double white flowers.—In Sáler Gardens.

Sapotaceæ.—Bassia latifolia. (Mahwa), mentioned last year. There appear to be 2 varieties, the one with red and the other with green leaves.—Both in great numbers above the Ghâts near Pimpalner, and also common in the Dangs.

Ebenaceæ.—Diospyros exsculpta (Temburni), a small tree with large leaves downy beneath; fruit edible with rather pleasant flavour.—1500 feet.

Apocynaceæ.—Carissa Carandas, a spinous shrub with shining coriaceous leaves, and fragrant white flowers; purple berry with sweet acid pulp; flowers in March.—Common everywhere.

Wrightia tinctoria (Kála Kura), a small tree or shrub with white wood, and lax panicles of fragrant white flowers appearing in April; style very short and anthers low down the tube.—Common everywhere.

Holarrhena antidysenterica (Doli Kurli), a shrub very similar to the above, but with wider leaves, and puberulous flowers having partially coherent anthers which form a pyramid above the limb of the corolla.—Common everywhere.

Asclepiadaceæ.—Calotropis Gigantea (Madár), a shrub abounding in milky juice, opposite leaves and interpetiolar umbels of purple flowers.—Common on all clearings.

Bignoniaceæ.—Bignonia Quadrilocularis (Waras), a very handsome tree when in full bloom with its large bunches of crimped white flowers.—Valleys and up to 1500 feet.

Cordiaceæ.—Cordia Myxa (Bhokar), a small tree with simple alternate leaves, panicles of white flowers, and edible berries with glutinous pulp.—1500 feet.

Verbenaceæ.—Tectona Grandis (Sagwan), the teak tree.—Valleys and up to 1500 feet.

Gmelina arborea (Sheoni), with opposite entire leaves, velvetty beneath; inflorescence a raceme; drupes yellow, superior, calyx persistent; fruit much eaten by wild animals.—1500 feet.

Vitex Nirgundi or Bicolor (Nirgundi), a shrub with opposite 3 or 5-foliolate leave and panicles of small bluish purple flowers.—Common in valleys and above the Ghâts.

Euphorbiaceæ.—Phyllanthus Emblica (Aonla), a small tree with axillary clusters of flowers; drupe fleshy, edible.—Valleys.

Urticaceæ.—Ficus benghalensis (Waror Bar), the Banyan tree.—Common everywhere.

Ficus religiosa (Pipal), with cordate, narrowly acuminate leaves.—Everywhere.

Ficus pseudojicola (Pipri), a tall handsome tree with long petioled, oblong-ovate, shining leaves.—Common.

Ficus cordifolia (Pâer), a tree with leaves somewhat like those of the Pipal, and clusters of small sessile round fruit.—Common.

Ficus glomerata (Umbar), a crooked tree covered with figs, purple when ripe, and always full of worms or flies.—Common especially by streams.

Artocarpaceæ.—Artocarpus integrifolia (Panas), the Jack tree, with shining dark green coriaceous leaves and huge fruit with shagreen exterior.—Western borders of Dangs.

Orchidaceæ.—I saw several specimens on trees, but none in flowers.

Amaryllidaceæ.—Crinum parvum (Karwand), stem about 9 inches high, about 3 white flowers in umbel; the bulbs were generally so fixed in the crevices of rocks that they could not be taken out whole; flowers in May.—Common on tops of Dang hills and on the Ghâts.

Palmaceæ.—Borassus flabelliformis (Târi), tapped for its saccharine juice, drunk under the name of târi or toddy.—Common in the western Dangs and again at the foot of the upper Ghâts.

Phœnix Sylvestris (Kajur), the common wild date palm; fruit yellow when ripe.—Western Dangs.

Gramineæ.—Eleusine coracana (Nágli or Násni), cultivated for food and export, being given to Banjâras in exchange for salt.

Oryza sativa (Chokha), common rice, occasionally raised in small quantities for food.

Holcus spicatus (Bâjri), cultivated for food.

Bambusa vulgaris (Welu), growing to 60 feet high in thick clumps.—Western Dangs.

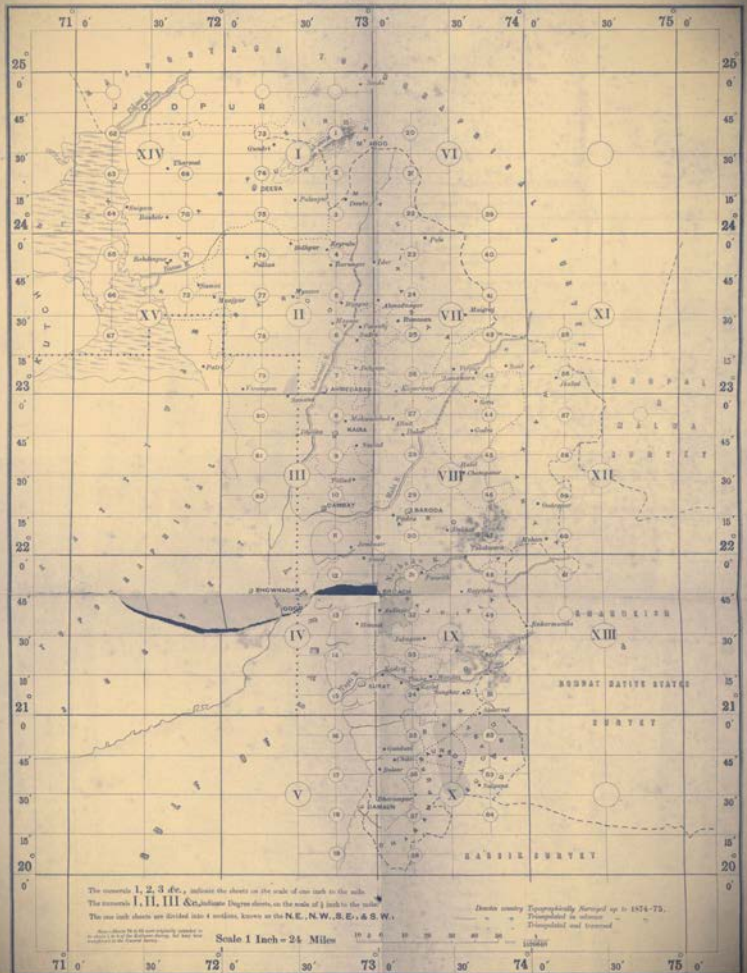
Bambusa stricta (Bâs), a small straight species of Bamboo with long thin branches.—Western Dangs.

Geology.

There is of course a great sameness in the lithology of the district, the greater part of the rocks varying from black to grey crystalline basalts, diorites, and the like. On the tops of several of the hills of the 'lower step' I met with rocks full of acicular white crystals. I saw very few large crystal masses. There are no alluvial deposits, and the rocks of the river beds are polished and rounded by the attrition of the gritty particles carried down by the monsoon torrents.

GREAT TRIGONOMETRICAL SURVEY OF INDIA

INDEX CHART OF THE GUZERAT TOPOGRAPHICAL SURVEY



The numerals 1, 2, 3 &c., indicate the sheets on the scale of one inch to the mile.
The numerals I, II, III &c., indicate Degree sheets, on the scale of $\frac{1}{4}$ inch to the mile.
The one inch sheets are divided into 4 sections, known as the N.E., N.W., S.E., & S.W.

Scale 1 Inch = 24 Miles

Denotes country Topographically Surveyed up to 1874-75.
" " Triangulated in advance.
" " Triangulated and traversed

Photolithographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Dun, November 1875.

TABULAR STATEMENT OF WORK IN GUZERAT, DURING THE FIELD SEASON 1874-75.

Triangulation.

Observer's Names.	Instrument used.	Area triangulated sq. miles.	No. of Stations visited.	3 Angles observed. Triangles.	3 Angles observed. Triangular error.	3 Angles observed. Error per mile.	3 Angles observed. No. of Heights.	3 Angles observed. Discrepancy in Height.	2 Angles observed. Triangles.	2 Angles observed. Error per mile.	2 Angles observed. No. of Points.	2 Angles observed. No. of Heights.	Remarks.
Lieut. J. E. Gibbs, ... (Recorder Bulwant Atmaram.)	Troughton & Simms' 10-inch	147* / 412†	27	35	4·6	1·7‡ in.	24	0·9§ ft.	138	4·1‖ in.	93	61	*Primary Triangulation. †Secondary Triangulation. ‡Mean diff. of 15 common sides. ‖Mean diff. of 40 common sides. §Mean diff. of 21 common heights.

Plane Tabling.

No.	Names.	Plane Tabling in Square Miles. 4-inch scale.	2-inch scale.	Stations per sq. mile.	Remarks.
1	Lieut. J. E. Gibbs, ...	37·3	.....	6·6	
2	Mr. D'Souza* ...	.....	.....	.....	*Employed the whole time in supervising natives and in teaching new hands.
3	„ Christie, ...	124·4	.....	13·3	
4	„ McAFee† ...	12·5	140.0	5·4	†Joined 31st December, was also employed in supervising natives and in teaching Mr. C. Norman.
5	„ E. J. Connor, ...	18·3	.....	22·8	
6	„ J. Hickie, ...	94·6	70·1	10·7	
7	„ G. D. Cusson, ...	95·4	57·8	7·8	
8	„ G. Hall‡ ...	18·3	.....	15·7	‡Transferred to Kattywar Party 9th January.
9	„ S. Norman, ...	93·7	.....	13·3	
10	„ C. Norman, ...	59·3	.....	11·5	
	Native Surveyors.				
1	Gopal Vishnu, ...	87·7	.....	12·5	
2	Raoji Narayen, ...	93·7	28·5	9·5	
3	Bhow Govind, ...	93·7	52·8	9·8	
4	Luximon Gorpuray, ...	39·0	.....	16·9	
5	Mukand Dinkar, ...	54·8	.....	11·0	
6	Ganesh Bapuji 1st, ...	58·1	51·2	11·1	
7	Govind Gopal, ...	37·8	.....	15·5	
8	Bulwant Rajaram, ...	39·0	.....	14·5	
		1057·6	400·4	average 10·7	Total No. of Plane Table Stations 15,636.
	Total, ...	or 1458 sq. miles			Including overlaps.

Traversing.

No.	Names.	Linear Distance in miles.	Remarks.
1	Mr. E. J. Connor, ...	3·619	A sufficiency of traverses has not been computed as yet for obtaining a fair average for the errors.
2	Ganesh Bapuji 2nd, ...	129·286	
	Revenue Survey.		
1	Jugal Mansukram, ...	169·555	
2	Gopal Ganesh, ...	117·110	
3	Trimbaklal Goverdhan, ...	27·984	
	Total, ...	447·584	
	Number of points fixed, ...	1133	

Permanent Drawing Office.

No.	Names.	Employment.
1	Mr. J. Peyton, ...	Head Draftsman.
2	Ganesh Narayen, ...	Draftsman left sick on 27th Decr.
3	Monaji Aboo, ...	Hand printing.
4	Luximon Gorpuray, ...	Printing from 29th January.
5	Mukand Dinkar, ...	„ „ 16th February.
	Revenue Survey.	
1	Keshowram Ravishankar,	Plotting Traverses and Revenue Survey fiscal details on Plane Tables.
2	Kuber Parbhudass, ...	
3	Dowlat Lalbhai, ...	
4	Parbhu Kisor, ...	

Extract from the Narrative Report—dated 15th November 1875—of Captain H. R. THUILLIER, R.E., Officiating Deputy Superintendent 1st Grade, in charge of the Kumaun and Garhwal and the Dehra Dun Survey Parties.

In the spring of 1874, the Establishment of the Kumaun and Garhwál Party was broken up into two detachments; one was sent under Mr. E. C. Ryall to resume the Survey of the higher ranges in Kumaun and Garhwál, the operations of which will be described hereafter, the other detachment, as per margin, under my own superintendence, was employed during the field season 1874-75 in carrying on the Survey of Dehra Dún which was commenced in the previous year.

PERSONNEL.

Captain H. R. Thuillier, R.E.
Lieutenant St. G. C. Gore, R.E., Asst. Supdt.

Surveyors and Asst. Surveyors.

Mr. C. J. Neuville.
" J. Low.
" L. J. Pocock.
" H. Todd.
" T. Kinney.
" E. P. Wrixon.

Native Surveyors.

11 Native Surveyors.

(2.) The field operations commenced early in October. Lieutenant Gore, was entrusted with the supervision of the village boundary traverses: Messrs. Low, Todd and Kinney, each with two Native Surveyors, were deputed to take up the topography of the Western Dún commencing at the Jumna. Mr. L. Pocock was directed to complete the triangulation of the Eastern Dún and subsequently to proceed to Jaunsár Báwar for the same purpose; and Mr. Wrixon to carry main traverses in the Eastern Dún for fixing trijunction pillars for checks on the boundary traverses.

Out-turn of work.

(3.) During the season, 225 square miles of country have been topographically surveyed on the scale of 4 inches to the mile; the triangulation of the Dún has been completed and the whole of Jaunsár Báwar covered with a net-work of triangles, comprising a total area of 470 square miles. 70 linear miles of main theodolite traverses, 328 miles of boundary traverses and 63 miles of check survey lines were run.

Topography.

(4.) The whole of the topography has been done most carefully and the measurements have been very searching. 63 linear miles of check survey were executed across the detail work of the Native Plane Tablers to test its correctness, and the hill sketching was examined *in situ* during the progress of the work. The results of these tests were very satisfactory and proved the work to be minutely accurate.

(5.) The area topographically surveyed is smaller than I had expected to have completed, but several causes tended to this result. The Native Surveyors with only two exceptions were raw hands and had to be taught Plane Tabling, for their work during the previous season (which was their first season of surveying) had been restricted to traversing. Their progress too when trained proved far slower than I had anticipated, so that the brunt of the work fell on the European Assistants. This in a great measure however was due to the intricacy of the ground, and the large amount of detail met with throughout the ground over which the topography was carried. The tabular statement will shew this by the amount of chaining and the large proportion of plane table stations which were found requisite for filling in the interior details. For the first 3 months of the field season also, the luxuriant vegetation for which the Dún is proverbial and the high *bhábur* grass which covers a large proportion of the low-lands, proved a great obstacle to the progress of the Plane Tablers. This grass is generally burnt in the month of February and until that time the surveyor is much delayed by having to cut lines for his chain measurements. The field season also was shorter than I might have made it, but this I was compelled to cut short owing to the large amount of mapping which had to be undertaken during the recess, this having been greatly augmented by the large area brought in by the Kumaun and Garhwál detachment during the same season. Under these circumstances and bearing in mind that it was our first season of working on the 4-inch scale, I trust this out-turn will be considered satisfactory.

Traverses.

(6.) The whole of the traversing required for the completion of the Survey of the Dún was finished. All precautions, as described in my last report, were taken to insure accuracy of results. The main theodolite traverses were in all cases run between trigonometrical stations, but in consequence of the ground being more rugged and broken than that met with in the previous season, the ratio of error is somewhat larger, though still satisfactory.

Boundary traverses and their errors.

(7.) The boundary traverses were all completed and comprise 121 villages and estates. These traverses are in all cases well tied in by check points furnished either trigonometrically or by the main theodolite traverses. They were executed by the Native Surveyors with the plane table and circular protractor, and were all reduced in the field and found to stand the usual tests in a satisfactory manner. The ground was more or less bad throughout for chaining, especially about the low-lands at the foot of the hills, a large portion of

the work having to be carried over broken ground and ravines with steep declivities, the measurements of which required very heavy corrections for reduction to the horizontal level. The boundaries also were very intricate, the average distance between each station in 5726 stations being only 4·58 chains. Notwithstanding these trials, the errors are very fairly small.

Remarks on the country.

(8.) The country surveyed during the season comprises ground of every variety, from the flat cultivated lands in the vicinity of the Asan, a tributary of the Jumna and the main drainage channel of the Western Dún, to the crest of the Mussooree range which rises to a height of over 7000 feet above sea level. The low spurs and broken ground about the foot of the hills gave an infinity of labour and trouble in surveying, being for the most part covered with thick Sál forest and cut up by deep precipitous ravines and 'raus' with beds of boulders lower down; these raus spread out leaving broad undulating plateaux between them which are for the most part well cultivated, except in places where shingle crops out.

Aneroid heights.

(10.) Numerous heights, in addition to those obtained trigonometrically, have been fixed by Aneroid barometers throughout the season's work.

Triangulation and Traversing in advance of the detail survey.

(11.) The amount of triangulation and traversing in advance of the portion topographically surveyed, covers in the Dún an area of 125 square miles, this being the extent of the Zamíndárí lands which remains to be surveyed by this party. In addition to this, the whole of Jaunsár Báwar, comprising an area of about 360 square miles, is ready for the topography to be commenced. The survey of this portion of the district which is composed entirely of hills and mountains, is to be done on the scale of 2 inches to the mile and will admit, I am afraid, of little are no traversing.

(12.) I now proceed to report separately on each officer's work, the details of which are tabulated on page 45—a.

Lieutenant Gore, R.E.

(13.) Lieutenant Gore took the field on the 7th October and was employed until 22nd November in superintending the village boundary traverses in the neighborhood of Rájpur and Dehra. On relieving him of this duty I entrusted him with the topography of sections 13, 14 and 24 bordering the Jumna. Having completed these sections, he took up sections 38, 39 and 49 in the beginning of February. About the middle of March, I sent Lieutenant Gore's party to complete all the low village lands lying among the forest of the Eastern Dún, in the vicinity of the Song and Suswa; this being the most favorable time of the year for surveying this ground, on account of the *bhábur* grass being all cleared and its freedom from the malaria of the neighbouring marshes. Much of this land is covered with rank vegetation nourished by the amount of water furnished by these streams and their numerous tributaries. The greatest obstacles to the survey being the cane brakes which were inaccessible to man or elephant. Lieutenant Gore with the help of the Native Surveyors completed the work allotted to him by the 20th April. Lieutenant Gore having been transferred to the topographical branch of the department, I have much pleasure in recording the valuable assistance I have invariably received from him since he has been under my orders, during which time he has conducted his duties with ability and energy to my entire satisfaction, and I consider him in every way qualified for independent charge of survey operations.

Mr. Neuville.

(14.) Mr. Neuville was employed the whole season in my office in the miscellaneous current work of which there was a large amount.

Mr. Low.

(15.) Mr. Low was employed all the season in Plane Tabling. He commenced on section 7 in the Khádir lands of the Jumna, where he experienced much delay from the high grass which covers all that portion. In January he took up the north and east portions of section 27 which was most intricate and difficult ground, cut up by deep ravines and low hills covered with forest. He then completed the hilly portion of section 37, and leaving his two Native Surveyors to fill in the low ground, he commenced section 46, which consists entirely of hills and runs up to the Mussooree and Landour settlement. By the end of the season he completed this section and section 57 which also consists entirely of hills. I was well satisfied with Mr. Low's diligence and the accuracy of his work.

Mr. L. Pocock.

(16.) Mr. Pocock was employed from the middle of October till the beginning of April on triangulation. He first completed the remaining portion of the Eastern Dún covering an area of 110 square miles, and on 22nd January started for Jaunsár Báwar, the triangulation of which he successfully completed by the end of March. This portion of his work embraces an area of 360 square miles, which is well covered with points. I have every reason to be well satisfied with Mr. Pocock's exertions and the results of his work.

Mr. H. Todd.

(17.) Mr. Todd was employed on topography throughout the season. He commenced work on 19th October with two Native Surveyors and during the season completed sections 9, 15, 26 and half of 56. Of these sections the ground in 15 and 26 was most intricate and difficult. The delineations of the features have been very artistically and faithfully rendered and the varied character of the ground has been shewn with excellent effect, but the labour involved in surveying such a large amount of detail was great and very tedious. The work of the Native Surveyors was rigorously examined. Section 56 consists entirely of hills, the ground being very precipitous and difficult to move about in. This portion of the work was also done with Mr. Todd's usual care and accuracy and the quality of his work is highly creditable to him. Mr. Todd closed work on the 30th April.

Mr. Kinney.

(18.) Mr. Kinney commenced field work on 17th October and was engaged in Plane Tabling during the entire season. He was first entrusted with sections 3 and 8 in the low ground of the valley of the Asan, and was provided with two Native Surveyors whom he had to train. He completed these sections by the 20th January, when I transferred his Native Surveyors and sent him to take up the topography of the hills in sections 25, 35 & 36. The ground in the two former of these sections is high with bold open features rising to a height of about 7000 feet and was easy to sketch, but in the central and lower portions of 36, the hills are much broken up into small confused masses, covered for the most part with forest and intersected by narrow and intricate ravines, resulting in an unusual amount of detail in the smaller natural features. A portion of this section which I had hoped to have had completed had to be left for the next field season. Mr. Kinney has worked hard and well, his sketching and delineation of ground is remarkably good and characteristic.

Mr. Wrixon.

(19.) Mr. Wrixon was employed in minor triangulation in the rough ground between the Dehra and Rájpur road and the Song Nadi. He subsequently took up the traverse of the road from Dehra to Hardwár and then carried a line up the right bank of the Ganges from Hardwár to Tapoban. I regret I am unable to report favorably of Mr. Wrixon's work or conduct.

Native Surveyors.

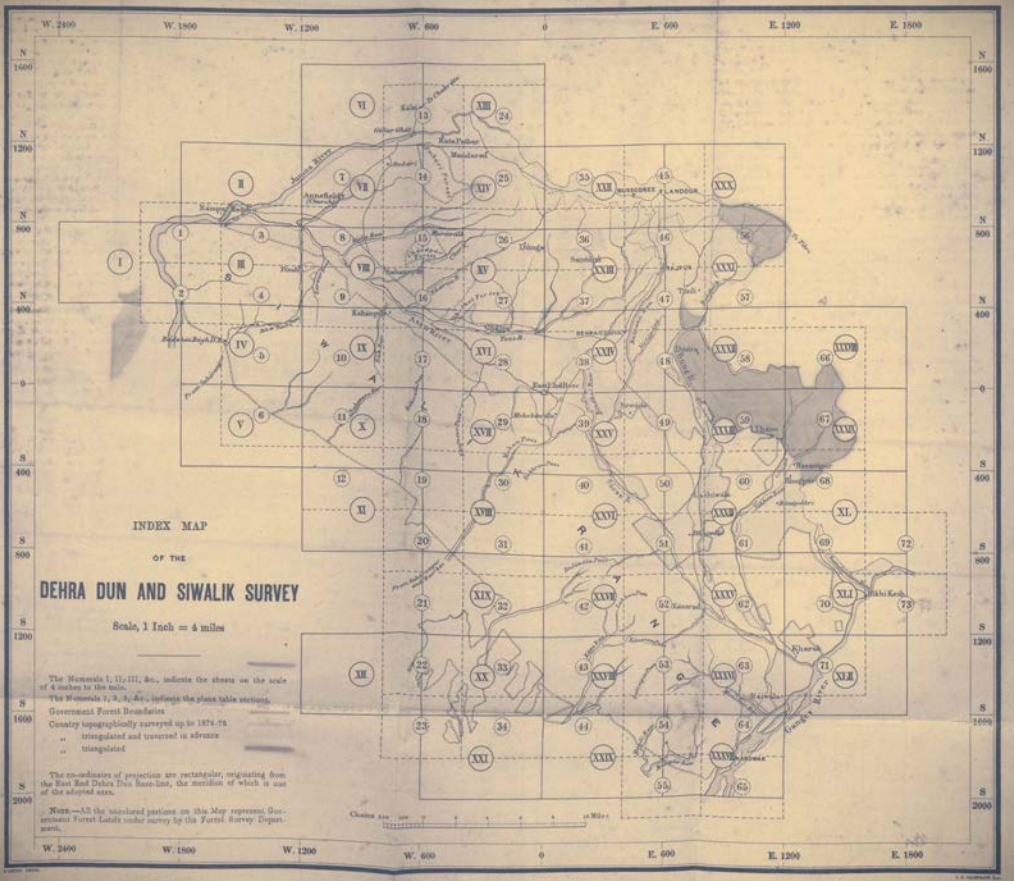
(20.) The topography done by the Native Surveyors, considering that it was their first season in Plane Tabling, was very fair and found to be minutely accurate, but they are very indifferent draftsmen. In this however they are improving, and will I have no doubt next season turn out more artistic work. I have been well satisfied with the diligence of all the Native Surveyors with two exceptions, one of whom was discharged and the pay of the second reduced.

Recess of 1875.

(21.) The party was employed during the recess on computations and mapping. All the computations connected with the previous season's triangulation and traversing were completed. The mapping includes the preparation of 7 Sheets of the Dehra Dún Survey on the scale of 4 inches to the mile which have been completed and sent to the Head Quarter's Office for publication.

Programme for field season 1875-76.

(22.) The detail survey of the remaining portion of the Zamíndári lands in the Dún will be resumed and completed. The topography of Jaunsár Báwar, on the scale of 2 inches to the mile, will also be taken up by a portion of the party at the commencement of the field season, and I trust to be able to complete the survey of this portion of the district also during the ensuing season.


W. 2400
W. 1800
W. 1200
W. 600
0
E. 600
E. 1200
E. 1800
N 1600
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N 800
N 400
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S 400
S 800
S 1200
S 1600
S 2000
INDEX MAP
OF THE
DEHRA DUN AND SIWALIK SURVEY
Scale, 1 Inch = 4 miles
The Numerals I, II, III, &c., indicate the sheets on the scale of 4 inches to the mile.
The Numerals 1, 2, 3, &c., indicate the plane table sections.
Government Forest Boundaries
Country topographically surveyed up to 1874-75
" triangulated and traversed in advance
" triangulated
The co-ordinates of projection are rectangular, originating from the East End Dehra Dun Base-line, the meridian of which is one of the adopted axes.
NOTE.—All the uncoloured portions on this Map represent Government Forest Lands under survey by the Forest Survey Department.
Chains
Miles
DEHRA DUN
MUSSOORIE
LANDOUR
RAJPUR
Annefield
Kaluwala
Kaita Pathar
Mandarwal
Rajpur
Sahastradhara
Tiuni
Kalsi
Kharsali
Chakrata
Jaunsar
Bhabar
Tarai
Siwalik Range
Asan River
Song River
Rispana River
Tons River
Jumna River
Ganges River
Kyarda
Nowgaon
Mussoorie
Landour
Rajpur
Kharsali
Kalsi
Chakrata

DEHRA DUN SURVEY.

Tabular statement of out-turn of work. Season 1874-75.

Details of Triangulation.

OBSERVER'S NAME.	Instrument used.	Area triangulated in square miles.	No. of stations visited.	No. of points fixed by intersection but not visited.	No. of stations whose positions and heights have been fixed.	No. of stations whose positions only have been fixed.	No. of hill tops cleared of forest.	Average number of trigonometrical points per square mile.	Average area in square miles to each trigonometrical height.	No. of triangles of which all three angles have been observed.	Mean triangular error.	No. of triangles of which only two angles have been observed.	No. of boundary pillars fixed.
	Inch.										"		
Mr. L. Pocock, ...	12	470	75	557	191	441	5	1·4	2·4	112	11	1064	7
„ E. Wrixon, ...	7	*20	23	39	...	62	...	...	...	7	40	103	15
Totals, ...	...	490	98	596	191	503	5	...	...	119	...	1167	22

* Approximate.

Details of Topography. Scale 4 *inches* = 1 *mile.*

NAMES.	Area in acres.	No. of acres per Plane Table Station.	LINEAR MILES.		REMARKS.
			Chain measurements.	Check lines.	
Lieut. St. G. Gore, R.E., ...	36,825	3·8	627·3	17·7	Level and broken ground.
and 4 Native Surveyors, ...	5,992	10·5	...	...	Hills.
Mr. J. Low, ...	15,404	2·3	329·0	19·3	Comparatively level ground.
and 2 Native Surveyors, ...	6,630	3·3	115·8		Ravines and low hills covered with forest.
	8,178	25·7	8·2	...	Hills.
Mr. H. Todd, ...	24,379	1·9	578·1	9·9	Very intricate ground consisting of ravines and low hills mostly covered with forest.
and 2 Native Surveyors, ...	4,600	19·4	...	...	Hills.
Mr. T. Kinney, ...	22,620	7·0	233·6	15·7	Partly level and partly ravines and low hills.
and 2 Native Surveyors up to 20th January, ...	15,760	22·1	...	...	Hills.
Mr. E. Wrixon, ...	3,369	11·2	40·4	...	Flat and tolerably open ground.
Totals, ...	1,43,757 or 224·6 sq. miles.	...	1932·4	62·6	

Details of Traversing.

NAMES.	Linear miles of traverse.	Number of stations.	Average distance in chains between stations.	Average error per 1000 links.	Average angular error.	REMARKS.
Mr. E. Wrixon, ... (Theodolite traverses)	70	271	20·67	1·00	11"	
Native Surveyors, ... (Plane Table and protractor traverses)	328	5726	4·58	2·90	...	
Totals, ...	398	5997	...	...	...	

KUMAUN AND GARHWAL SURVEY.

(23.) My last report treated the operations of this party up to the beginning of July 1874, when it returned to recess quarters at Almora, which place was selected on account of its being close to the ground of field operations—a matter of much importance on account of the limited period in which survey operations could be carried on in the higher snowy ranges. Experience has proved that the best time for operations in these high altitudes is immediately after the rainy season, when the snow line is at its highest and the atmosphere bright and clear.

(24.) The party, which consisted of the members as per margin, had but a short rest at Almora and made an early start for the field while the rains were still in progress. This involved much discomfort on the march and some risk of malarious fever, but was necessary in order to secure every day of the short time available for surveying.

E. C. Ryall, Esq. Asst. Supdt.

Assistant Surveyors.

Mr. C. H. McAfee.
„ E. F. Litchfield.
„ I. S. Pocock.
„ J. F. McCarthy.

(25.) Mr. Ryall has submitted the following report of the operations under his charge.

"Active operations were commenced on all sides by the 13th September.

"It was my original intention to conduct a series of triangles along the Tibetan frontier with a view of laying down peaks, &c., in the Sutlej Valley. I abandoned this project when I learnt that the undertaking would press too heavily on your estimate of expenses. I proceeded instead therefore to inspect the topographical work finished during the previous summer and the ground where the Plane Tabling was about to be done. After completing my inspection tour, I proceeded to continue the Milam triangulation. The total length of the Milam triangulation is 48 miles, of which 32 was finished during previous and 16 during the season under review. The greater portion of this work was very trying; it required all the skill and nerve I possessed to pierce to stupendous gorge overhung by the lofty snowy mountains of Chirkhana and Hasaling with a series of triangles. The steepness of the gorge may be conceived when it is understood that the direct horizontal distance from Hasaling snowy peak to the Gori river is rather less than 1¾ miles and that it towers 14,000 feet above it. In this triangulation Mr. McAfee assisted me by observing at three of the base stations.

"The extent of triangulation finished by me covers an area of 200 square miles, comprising five stations visited of an average height of 13,300 feet above sea level.

Description of country.

"As far as regards altitude and physical formation, the two districts of Kumaun and Garhwál may be divided into five belts or zones. I shall describe these in succession beginning with No. 1 from the north.

No. 1 Zone. The average width of this belt is about 15 miles. In length it extends from the Mána Valley in the west to that of Byáns, bordering on the Nepal frontier, in the east. It comprises within it, besides the two above mentioned valleys, those of Niti, Milam, Rálam and Dharma. The average height of the basins of these valleys is about 14,000 feet above sea level, the highest basin (15,500) being that of Mána and the lowest (12,500) that of Byáns. The average altitude above sea level of the main and minor ranges within this belt is about 20,000 feet. The ground though lofty, is for the most part undulating. Access to the tops of most of the spurs or ranges is not difficult, though very trying in consequence of the great tenuity of the air. With the exception of the main ranges which divide the above mentioned six valleys, the whole formation of this zone is of slate of almost every conceivable color and in various stages of decay.

The ranges that are excepted, are entirely composed of granite, that is so far as I could judge, for I could not perceive any or the slightest order of stratification among them. Fuel can be seldom had over 12,500 feet; grass never over 13,500.

No. 2 Zone. This belt consists of ranges of extremely precipitous and rugged lofty mountain barriers running parallel to and south of Zone No. 1. Its average width may be put down at 10 miles, its maximum is about 17. The whole of these ranges are stupendously lofty, the mean height of the peaks on them being about 22,000 feet, and the formation throughout is of granite, except in some few places where it is of gneiss. The drainage from the comparatively undulating and open valleys of Mána, Niti, Milam, Rálam, Dharma and Byáns lying in Zone No. 1, breaks through these enormous barries, and the six gorges so formed average in mid height about 4 miles in breadth. The widest, the gorge of the Niti or Dhauli river, towards Joshimath, being about 6 miles. The narrowest is that of Milam being about 3 miles. The sides of these gorges are overhung, as a matter of course, by almost sheer precipices, capped by towering needle-like peaks. The easiest of them, where the triangulation has been carried through, were converted into stations, ascent to most of which was not accomplished without imminent risk of life. The widest portion *viz.*, 17 miles of this

belt consists entirely of a wild and uninhabited valley called the Rishiganga, at the head of which is the Nanda Devi mountain 25,669 feet high. This valley is extremely precipitous and broken; the ground beyond the first 7 or 8 miles consisting of bare rocks, snow-beds and glaciers, with no signs of vegetation. The hills fall abruptly down to the river which dashes like a torrent between perpendicular walls of rock, which form its banks.

"No. 3 Zone consists of from 6 to 7 miles of spurs emanating from the foot of the snowy ranges and running mostly in a southerly direction. The average height of these spurs is about 12,000 feet above sea level; they are composed partly of stratified gneiss and partly of crystallized lime-stone, the former occurring about 4 miles towards the north and the latter about 3 miles towards the south. In consequence of the stratified nature of their formation, the spurs are, as a rule, precipitous on one side and sloping on the other. The surveyors working among them had no difficulty therefore in getting about.

"The operations of the snow party under my direction were almost entirely confined to ground in the above three zones. It may be thought perhaps that to treat similarly the remaining portion of Kumaun and Garhwál previously surveyed, would be irrelevant to this report. In order however not to leave the subject in an incomplete form, I shall proceed in a cursory manner with the description of the remaining zones.

"No. 4 Zone is by far the broadest; it averages about 50 miles, and the average height of the ranges in it is about 7,000 feet above sea level. The differences however between the heights of contiguous spurs are so trifling, that to one looking at the whole of this belt of country from a commanding point, all the ranges would appear to be nearly of one uniform height, no great contrast is to be seen anywhere. The width of this zone is greatest in Kumaun and least in Garhwál. From any point in the middle of this zone and from its southern extremities, the snowy ranges appear to rise very abruptly and seem to gird its northern limits like an immense wall, towering about 12,000 feet above it. Unlike the mountains found in most parts of the Himalayas, as far as I have seen of them, the mountains in this 4th zone appear to be much waterworn and so present very minute and intricate features. They have given topographical surveyors much hard work, entailing upon them at the same time the exercise of much judgement as to what detail should be suppressed, in order to make room for expressing the more important features. With the exception of some portions lying towards the north which is of gneiss, the principal formations are of lime-stone, slate, mica-schist and quartzose rocks.

"No. 5 Zone. This might be called the Siwalik formation of Kumaun and Garhwál. Kumaun has very little of it, the widest part in it lies to the west of Káládhúngi where it is about 8 miles. To the east of Káládhúngi this formation loses much of its Siwalik like aspect, and might be termed simply a sand-stone range, of an average height of about 4,000 feet having an average width of about 5 miles. Garhwál however has the largest share of this sand-stone formation. The widest tract of the sand-stone country in this district, consists of the Patli and Kotli Dúns, which average in breadth about 12 miles, inclusive of the outer ranges girding them. The average height of the ranges in this last or sand-stone zone, with the exception of that noted as lying in Kumaun to the east of Káládhúngi, is about 2,000 feet above sea level.

Mr. McAFee.

"Mr. McAFee was entrusted with the triangulation of the country about Choudans, which lies at the foot of the Dharma and Byáns Valleys. He succeeded with praiseworthy application in getting through about 600 square miles of triangulation by 24th November, when he closed work and retraced his steps to Naini Tal.

Mr. Litchfield.

"Mr Litchfield was deputed to take up the Plane Tabling of the southern half of the Níti Valley and of the valley of the Rishiganga river, a description of which has been already given. On completing these sections he was directed to resume work in the higher valleys of the Pindar river. He accomplished the work allotted to him in a very creditable manner but not without undergoing great exposure and privations especially in the Rishiganga Valley, the survey of which is perhaps the most formidable undertaking in the whole range of the Himalayas yet accomplished. The amount of his field work consisted in sketching an area of 837 square miles. Considering the quantity and quality of his sketching, he deserves much credit for his successful labours.

Mr. I. Pocock.

"Mr. I. Pocock was entrusted first with the sketching of the upper portion of the Mána Valley, in sections 21, 22 and 29, which he successfully completed by 5th October.

"Mr. Pocock's survey of this portion of the Mána Valley, was a most arduous and enterprising feat for which he deserves much commendation. On the completion of this piece of work Mr. Pocock was directed to resume the sketching of the Jowar Valley, which he had been obliged to relinquish

in the beginning of July owing to the inclemency of the weather. After doing this, he completed section 63 and a portion of 62 lying on the eastern frontier of Kumaun from which he made a reconnoissance of the Nepal border. He then retraced his steps towards Rudrprayág in Garhwál, to sketch a small portion belonging to section 8, which had been inadvertently omitted when the survey of that part of the country was done. Advantage was taken of this opportunity to provide Mr. Pocock with aneroid barometers, for the determination of heights of places along his route from Almora *vid* Srinagar through Tihri-Garhwál to Landour.

"Mr. Pocock after an arduous field season closed work on 20th March and arrived at Dehra on 31st March.

Mr. McCarthy.

"From what I could learn of the ground in the Niti Valley, I formed an opinion that the upper portion was, though very lofty, yet comparatively easy to survey; I therefore made over this portion to Mr. McCarthy, as he was the least experienced hand in the party. He accomplished the undertaking with credit, for it was accurate. His rendering of the ground, as far as giving adequate expression to the features, was however very poor.

"I have good reason to anticipate that more than ordinary difficulties will be met with in the north-eastern frontier of Kumaun in the valleys of Dharma and Byáns, the survey of which remains to be done. Their inhabitants are notorious for rascality and drunkenness, in fact they are little better than mere savages, and their proximity to the Nepal and Tibetan frontiers, renders them a very difficult people to deal with."

Out-turn of work.

(27). The area topographically surveyed on the scale of 1-inch to the mile, comprises 2,176 square miles and the portion of country triangulated covers 800 square miles. I cannot abstain from drawing particular attention to the survey of the upper part of the Mána Valley, a most difficult undertaking successfully performed by Mr. I. Pocock. In an area of 108 square miles, the average height of the ground surveyed was over 21,000 feet, the average height of the Plane Table stations was 19,500 feet and the maximum height visited by Mr. Pocock was 22,040 feet above sea level. This value was obtained differentially by observations of the boiling point at the place itself and at a trigonometrical station of known height, and approximates to the greatest height reached on any mountain by man. The Messrs. Schlagentweit in 1855, *Vide* their Vol. II, India and High Asia, ascended the flanks of this same mountain, Kamet (their Ibi Gámin), to a height of 22,259 feet, on an undefined spot, the height of which they obtained from observations with a mountain barometer, and Mr. W. H. Johnson in the report of the survey operations in Kashmir for 1863-64, is said to have visited a point "upwards of 23,000 feet above the sea". The whole of the topographical work was in very elevated regions and the ground in which Messrs. Litchfield and McCarthy were employed, was not very far below that of Mr. Pocock's in point of height. In these barren and inhospitable regions, besides the natural physical difficulties which were in themselves very trying, the commissariat arrangements were a source of much anxiety. On considering the trials of such an enterprise, the risks that must have been incurred in ascending mountains of such stupendous height and in traversing glaciers, the physical exertions in such rarefied air and the exposure to extreme cold, I think it will be admitted that these operations were of a most arduous nature and that Mr. Ryall and the Assistants employed under him are deserving of great praise for their energy and determination in overcoming such difficulties.

Recess of 1875.

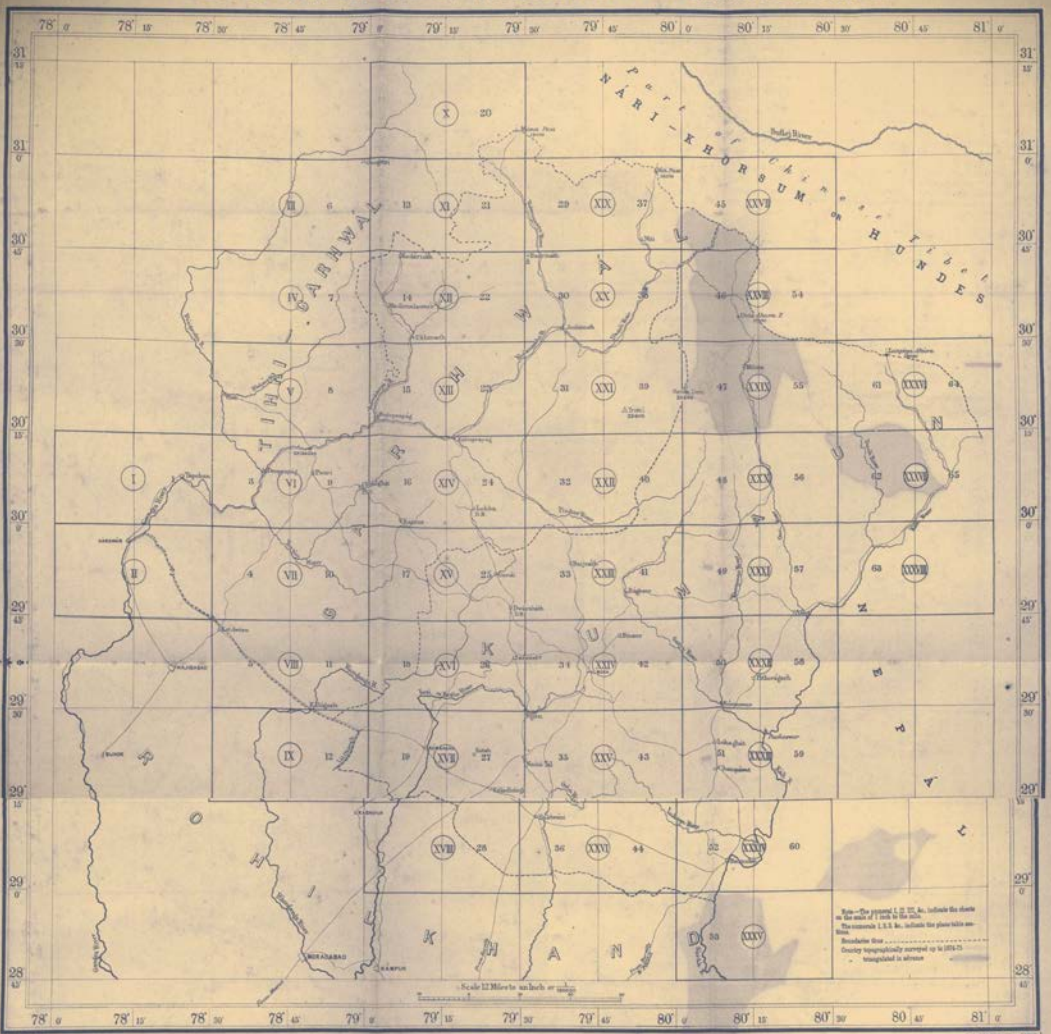
(28.) During the recess this portion of the party was engaged in the computations of the snow triangulation and in the preparation of the fair maps of the Kumaun and Garhwál Survey. The following sheets have been completed and submitted to the Photozincographic Office for publication.

Skeleton sheets Nos. VI (2nd edition) XI, XII, XIX, XX, XXI, XXII, XXIII, XXXI, XXXVIII.

Shaded sheets Nos. XII, XXII, XXXVIII.

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

INDEX TO THE SHEETS OF THE KUMAUN AND GARHWAL SURVEY.



COMPILED UNDER THE DIRECTION OF KLAUS T. G. MONTGOMERIE, R.E., 1875. SURVEY GREAT TRIGONOMETRICAL SURVEY OF INDIA.

Photozincographed at the Office of the Superintendent, Great Trigonometrical Survey, in Calcutta, December 1875.

KUMAUN AND GARHWAL SURVEY.

Tabular statement of out-turn of work. Season 1874-75.

Details of Triangulation.

OBSERVER'S NAMES.	Area of triangulation in square miles.	Number of stations visited.	Number of triangles completed.	Number of intersected points fixed.	Number of points whose heights have been determined.	Average altitude in feet above sea level of stations visited.	REMARKS.
Mr. E. C. Ryall, ...	200	*5	†5	0	5	13,300	* Mr. McA'Fee assisted Mr. Ryall by taking observations at 3 of the base stations. The area about 50 square miles embraced by these stations has been included in the out-turn shewn against Mr. McA'Fee.
Mr. C. H. McA'Fee, ...	600	21	18	56	40	11,500	† Angles observed at 2 of the forward stations during previous field season contribute towards making up this number.
Totals, ...	800	26	23	56	45	...	

Details of Topography. Scale 1 *inch*=1 *mile.*

NAMES.	Area surveyed in square miles.	Average number of Plane Table stations per square mile.	IN FEET ABOVE SEA LEVEL.			Area of glaciers in square miles.	REMARKS.
			Average height of ground surveyed.	Average height of Plane-Table stations.	Maximum height of points visited.		
Mr. E. F. Litchfield,	309	0·30	20,000	17,500	19,200	55	Very rugged and precipitous ground, principally in the Rishiganga Valley. Includes 50 square miles of reconnoissance of the eastern portion of that valley.
	348	0·40	17,000	15,000	17,000	12	About the upper sources of the Pindar river. Ground partly very rugged.
	180	0·60	12,500	11,000	15,000	...	About the lower parts of the Pindar and Rámganga Valleys; ground easy.
„ I. S. Pocock,	108	0·50	21,200	19,500	22,040	49	Bold high ground in the upper part of the Mána Valley, culminating in some of the loftiest Himalayan peaks.
	614	0·90	12,500	11,500	14,500	11	About Jowar and Choudans; ground easy. Includes 187 square miles of reconnoissance of the Nepal border.
	2	†4·00	†2,800	†2,100	3,500	...	About Rudrprayág on the Alaknanda river; ground easy, details very intricate.
„ J. F. McCarthy,	330	0·94	20,500	18,000	20,500	41	Bold and commanding ground about the upper parts of the Niti Valley, partly precipitous and partly undulating.
	305	1·10	18,000	12,500	15,000	...	Chiefly to the east and west of Joshimath; ground partly rugged and generally otherwise.
	2176	*0·68	*17,400	*15,000	...	168	* These averages do not include the quantities marked thus †.

Extract from the Narrative Report—dated 15th July 1875—of Captain J. R. McCULLAGH, R.E., Officiating Assistant Superintendent 1st Grade, in charge Leveling Party.

Movements of the party.

(2.) On the 30th November 1874 operations were commenced at the S. W. end of the Bangalore Base, and the point of origin to which the heights of all the Bench-marks are referred, is the metal plate in the floor of the observatory at or about ground level. The trigonometrical value of this has been taken at 3117·775 feet.

(3.) From this the line of levels was carried *viâ* Túmkúr, Sira, Hiriyur Tallak and Rámpur to Honúr H. S. and into Bellary, continued *viâ* Alúr, Adoni, Mádawáram; and the season's work was closed at Raichore Railway Station on the 3rd April 1875.

(4.) On the 5th the return march, about 257 miles in length, was commenced and the party reached Bangalore on the 30th April.

Conduct of the operations.

(5.) Before commencing operations the collimation of the levels was adjusted; it was again examined on the 1st February and finally tested on completion of the work, when one level was found to be almost in perfect adjustment and the other only very slightly thrown out.

(6.) The staves were compared with the portable standard bar on the 9th December, on the 1st February and finally on the 3rd April, the day on which work was closed.

(7.) Throughout the season the rules and instructions laid down for the conduct of leveling operations, were strictly adhered to.

Nature of the country.

(8.) From a short distance out of Bangalore, the general appearance of the country passed through is bare, uninteresting and far from picturesque; although it is decidedly undulating, and might in some places be called hilly, until the neighbourhood of Bellary is approached, but from that on to Raichore there is not much to complain of in the way of impediment to leveling.

(9.) For the first 18 sections the sum of the rises and falls, passed over by the staves, gives an average of 65·7 feet per mile; up to section 42 this was slightly reduced being 60·3 feet. As far as section 59 it becomes 55·1 feet; and over the whole line the average rise and fall stands at 47·9 feet per mile.

(10.) During the operations the roads were kept to as far as possible, but the line was carried across country for a distance of about 33 miles.

(11.) The Haggri and Tungabhadra rivers were met with, and had to be crossed; the former three times, first by a bridge at Hiriyur, secondly about five miles from Honúr H. S. where there was not much water, but over a mile of deep sand, and thirdly at Moka village, where also there was little water but again about a mile and a half of very heavy sand in the river bed.

(12.) The Tungabhadra, at Mádawáram village, was a somewhat more formidable obstacle, being about half a mile across with high steep banks; the waterway was some 25 to 30 chains in width, but fortunately there were islands (of sand) which were capable of being made use of by taking a zigzag course.

Weather and its influence on the health of the party.

(13.) During the months of December and January, the nights and early mornings were very raw and cold, and heavy mists hung about until the sun was well up. From the middle of February it began to get warm, and before the close of the working season it was decidedly hot weather.

Out-turn of work.

(20.) The following is the out-turn of work for the season: 297 miles of double leveling embracing the determination of the heights of 210 Permanent Bench-marks, buildings, temples &c., &c; 2 Trigonometrical stations, Honúr H. S. and Bandúr Z. D. S. of the Great Arc Series; also the G. T. S. Bench-mark at the Mainwaring tank, Bellary, laid down by Lieutenant Harman, R.E., in the previous season; the "level of top of rails" at Bellary, Adoni and Raichore Railway Stations; 8 Bench-marks of the Public Works Department; and 16 Boundary pillars of the Revenue Survey.

At Raichore the usual G. T. S. Bench-mark has been engraved on the rock *in situ*, the position being indicated by a paka pillar, in a situation, outside the Railway Station Compound, convenient for the resumption of the leveling operations at any future time.

Office duties.

(21.) The computations are now complete and the following table shows a comparison between the determinations of height of a few of the points connected as obtained by G. T. S. Triangulation, G. T. S. Spirit Leveling, and the Madras and G. I. P. Railway Departments.

SITES.	Heights.	REMARKS.
S. W. end of the Bangalore Base,	3117·775	Origin of the spirit leveling operations season 1874-75, to which the values of all the Bench-marks are referred.
Bandúr Z. D. S., ...	1452 1452·075	By triangulation. „ spirit leveling.
Honúr H. S., ...	1583 1583·460	„ triangulation. „ spirit leveling.
Bellary, (Level of top of rails), ...	1484·16 1486·879	„ Madras Railway. From sea level at Madras. „ spirit leveling.
Adoni, (Level of top of rails), ...	1364·35 1368·193	„ Madras Railway. „ spirit leveling.
Raichore, (Level of top of rails),	1311·21 1314·83 1315·517	„ Madras Railway. „ G. I. P. Railway. From sea level at Bombay. „ spirit leveling.

Extract from the Narrative Report—dated 4th August 1875—of Captain A. W. BAIRD, R.E., Officiating Assistant Superintendent 1st Grade, in charge Tidal and Leveling Party.

The inspecting party at Hanstal Tidal Station.

(2.) When I visited Hanstal Tidal Station in August 1874, I found that there was a considerable deposit of fine mud in the small pipe in connection with the cylinder: this caused a slight retardation in the flow of the water from the sea to the cylinder and *vice versâ*. This of course had to be rectified as soon as possible; the cleaning out of the pipe was a difficult job, and Mr. Rendell completed it in a satisfactory manner, without losing more than a day or two of the work of the Self Registering Tide Gauge. When every thing was again in thorough working order, Mr. Rendell left with his detachment for Nawanár Tidal Station to await my arrival.

Remainder of party take the field and cross to Cutch.

(3.) Having made all preparations for commencing leveling operations, I took the field with the greater part of the Native Establishment on the 16th October and marched direct for Jorya. On my arrival there I at once engaged native boats to convey us across the Gulf to Mundra. We reached Mundra on the 21st October and camped there.

Visit Nawanár Tidal Station.

(4.) I visited Nawanár Tidal Station as soon as possible after my arrival at Mundra, and found Mr. Rendell engaged in the repairs of the platform round the observatory, which had suffered considerably from the heavy seas during the monsoon, since I had inspected the station in July.

Programme of work for field season.

(5.) Having examined the foreshore at Nawanár, I saw that nothing could be done as yet towards getting up the small iron pipe and the flexible pipe, as the sand bank had rather increased than otherwise, since I had last seen it. I could also trace a very decided difference in the configuration of the spit at the point where the creek joins the sea; so that I had hopes in 2 or 3 weeks that the bank would be washed down sufficiently for the pipe to be taken up, and moreover the wind was blowing strongly from the north which would drive the sand back along the coast. I then gave Mr. Rendell instructions for his work during the field season—that he should wait at Nawanár for a week or two and try to put the station in order as soon as possible, then take up the inspection of the observatories in turn, and generally keep the stations in working order. The daily morning reports from the stations came to my office during the whole field season. In this way Mr. Rendell was enabled to work advantageously: and at the same time I was kept informed of what was going on at each station, while I conducted the leveling operations.

Leveling operations.

(8.) The country between Nawanár Tidal Station and the mainland proper, is more or less a mud swamp or *Small Runn*, and is covered at the high tides of the 2 or 3 days following every new and full moon. I had therefore to wait until the very *low high tides* which would occur about the 2 days following the "Moon's first quarter" in order to drive the levels across this treacherous bit of ground satisfactorily.

(10.) While waiting to begin work, I had several iron pegs with flat plates fixed on the top, constructed to place the legs of the Level Stand upon, when working over shaky ground. I was in hopes that I should then be able to isolate the instrument to a certain extent, and so lessen the tendency of the bubble to move when reading the scale after the staff had been observed. To a certain extent this answered, but I soon became aware how futile this plan was, for the ground was painfully difficult to level over. I saw that I must modify the routine of working in order to obtain thoroughly good results of the leveling and at the same time get over a respectable distance per diem.

(11.) I therefore arranged that the second leveler should read the bubble scale, after I had observed the staff, while I actually had my eye at the instrument (for the slightest movement would have caused the bubble to move 4 or 5 divisions and perhaps one end to disappear altogether). I read the levels in the same way for the second leveler, while he observed with his level. Even with all this care, on this ground, and when crossing the portions on the Runn proper, we had often to take several sets of observations before they were perfectly satisfactory.

Range of the leveling operations.

(13.) The leveling operations were to be carried out in two sections, the first from Nawanár Tidal Station along the Cutch coast, across the Runn between Shikarpúr and Málliá, then along the Kattywar coast to Balumba, thence over another portion of the Runn to Haustal Tidal Station. The second series to commence at Haustal Tidal Station across the Runn to Jorya and thence along the Kattywar coast of the Gulf and across the small Runn of Okhá Mandal to Okhá Tidal Station opposite the Island of Bet. Branch lines of course were to be taken to such Trigonometrical Stations as were conveniently near the main line of levels. The Bench-mark stones properly cut had been laid down the previous year (3 at each Tidal Station) and the others about 10 miles apart along the route, and these had also been laid down with reference to the Trigonometrical Stations to be connected.

Nature of country on the Cutch side up to the Runn.

(14.) From Mundra to Shikarpúr the line to be leveled over was distant from the Gulf from 5 miles at Mundra to 15 miles at Anjár; the country was tolerably flat till within a short distance of Anjár, where we met with some steep hills and then descended again to about the same relative level as near Mundra. From Anjár the ground continued flat for a few miles and then became undulating almost right away to Shikarpúr. From Anjár to Shikarpúr the coast line (if I may use that expression for the demarcation between the mainland and the Runn) was from 5 to 7 miles distant from the line of leveling. One peculiar feature in the roads in Cutch, along which we took our levels, is that they are as a rule 2 or 3 feet and in some cases 5 feet below the general surface of the country in the immediate vicinity. I was more particularly struck with this when I had to visit Nawanár in the monsoon last year, for the roads then appeared more like small canals than anything else.

Great Trigonometrical Stations in Cutch connected.

(15.) The Trigonometrical Stations in Cutch which I connected were found to be in first-rate repair, and as they had been constructed more than 20 years previous to the time we visited them, it shows that with ordinary precautions on the part of the Native Authorities, our Survey marks ought to remain in perfect preservation. The stations I visited were either on the tops of hills or of some very high towers in the principal towns. I may mention that it took me the whole of a day and working as rapidly as possible to connect Butchow H.S., a distance of about $\frac{1}{4}$ of a mile from our main line.

Country on either side of the Runn between Shikarpúr and Málliá.

(16.) Between Shikarpúr and the Runn the country is almost entirely uncultivated, and there is a series of hillocks composed of fine black sand which are covered with dense vegetation. These hillocks appear to be moveable; they are dotted here and there over the plain, but the hillocks in the immediate vicinity of the Runn here are tolerably high, and form an almost uninterrupted chain for a mile or two to the west and running nearly parallel to the general line of the Runn.

On the Kattywar side opposite there are no hillocks but a tract of waste land for one or two miles which is cut up by a great number of Nullahs, then we find a mile or two of cultivated fields occupied by the "Meanas" (who are considered a race of professional thieves). The villages of these Meanas are scattered all over the country here, and there are some 200 of them near the town of Málliá. Each village consists of a few straw huts surrounded by a straw hedge, and

The Meanas

the flag of the headman of the village, is conspicuous in each case on a long bamboo stuck into the ground in front of his hut. These Meanas are considered most troublesome people by the Officers of the Political Agency.

The Runn between Málliá and Shikarpúr.

(17.) The Runn itself between Shikarpúr on the Cutch side and Málliá on the Kattywar side, is some 8 miles across; but of this only about 6 miles can be used for the determination of the general level of the Runn, as the ground close to the mainland on each side is from a foot to 18 inches higher.

There are two Bench-marks enclosed in large blocks of masonry in the Runn itself, and situated about one mile on either side of the centre line of the Runn. These Bench-marks were laid down about 10 months before the leveling operations were commenced, and had plenty of time to settle. This part of the Runn is perfectly dry from November till the end of March, but about the end of April or beginning of May, it is covered by the water from the extraordinary high tides, and the water is also forced up by very high south-westerly winds which always prevail at that time. The Hanstal creek, being almost like a funnel at the end of the Gulf, is acted on by the full force of this wind, and the water from the Gulf is thus conveyed far up the Runn.

The ground over which we leveled was almost quite dry and has the usual appearance, blackish grey colour with here and there patches of glistening white from the salt deposited after evaporation.

Arrangements for getting a true value of the level of the Runn at each point where staff was put up. Also for fixing the line of levels so that it could be re-leveled over the same points in future.

(18.) I deemed it a necessary precaution in leveling over the Runn both here and afterwards that the lines should be driven in a perfectly straight direction from point to point, and also that at each point where the staff was put up, I should get an exact value of the ground immediately round that point. Accordingly starting from the Bench-mark on the Runn nearer the Cutch coast, we leveled in a direct line to a point on the sand hill close to which there is a Bench-mark on the Cutch coast, *viz.*, Pathewalla Dhoi. Again the next line was taken directly between the two Bench-marks on the Runn, and a third section from the Bench-mark nearer the Kattywar coast direct to a point on the Kattywar mainland and closing on Bench-mark No. 2 Málliá.

At each point where a value of the level of the Runn was to be determined, the Muccadum was ordered to drive the pegs (very large ones) into the ground until the top was just flush with the surface; this he tested by a mason's level which he carried in his hand, the brad was then put in and he scraped away the earth all round to a depth of about $\frac{1}{2}$ an inch from the surface to allow the staff to turn freely: thus the level of every point on the Runn where the staff was put up will be evaluated.

Málliá to Balumba.

(19.) The country from Málliá to Balumba is almost entirely black soil and tolerably flat, and one or two pretty large streams had to be crossed.

The Runn from Balumba to Hanstal Tidal Station.

(20.) There are no Bench-marks between Balumba B.M. and Hanstal Tidal Station. The first 4 miles is across cultivated fields intersected by Nullahs, in most cases filled with fresh water. Having carried the line into the Runn, I made similar arrangements for determining the value of the different points where the staves were erected as before.

The work on the Runn as affected by the atmosphere.

(21.) In the very early morning the observations on the Runn are very satisfactory, every thing is so very clear, but after 9 o'clock, even in the cold weather, it is almost impossible to work except at ridiculously short distances, unless perhaps on a very cloudy day; on a clear day about noon and up to 4 P.M., the atmosphere has the appearance of water boiling hard, and taking observations at that time is of course out of the question. A heliotrope seen at a short distance looks like an immense flame of fire. Even at a mile distant everything seems doubled above and reflected underneath as well. Small scrub not more than 6 inches or a foot high look immense bushes, and in one place between Hanstal and Jorya, there is a patch of this about a mile across, which may be considered as well defined a feature on the Runn as a forest on a plain.

The first section closing at Hanstal Tidal Station.

(22.) The first section of leveling operations closed on the 3rd Bench-mark at Hanstal Tidal Station and finally on the planed surface of the bed plate of the S. R. T. Gauge.

The second section, Hanstal Tidal Station to Okhá, commenced: and the Runn from Hanstal to Jorya leveled over.

(23.) Having inspected the work at Hanstal Tidal Station, which was found satisfactory, and having seen Mr. Rendell at Jorya and made arrangements for getting up some extra piping from Bombay for Nawanár Tidal Station according to your wishes in order that 2 months work might be carried out for that station, from 7th March to 7th May, I again returned to

Hanstal and commenced the second section, Hanstal to Okhá. The origin was again the planed surface of the bed plate of S. R. T. Gauge. Similar arrangements were made as formerly for the Runn and we had some 14 miles of it to determine between Hanstal Tidal Station and Somarthal B.M. There are also 2 Trigonometrical Stations of the net-work series of the Kattywar party on this line. These served as closing and re-starting points for each day's work, and their heights were of course determined. From Somarthal B.M., the ground is slightly undulating, and within 1 mile of Jorya, is cultivated. Jorya T.S. was connected and also a Branch line of (10 miles) was taken to *Haditada* H.S., a principal station.

Jorya to Gúrgut close to the Runn of Okhá Mandal.

(24.) The line from Jorya to Okhá Tidal Station was taken *viá* Nawánagar and Khambhália to Gúrgut which is on the Kattywar side of the Runn of Okhá Mandal. The country as a rule was pretty flat with the usual cotton soil up to about 7 miles from Khambhália when it began to be hilly and the ground very hard and rocky. From Khambhália also to Gúrgut it was undulating and hilly the whole way. One or two rivers had to be crossed on this line; they were of course almost dried up at the time we were working.

The Runn of Okhá Mandal.

(26) The line of levels after passing Gúrgut had to be taken across the Runn of Okhá Mandal to Topni Ness B.M. in Okhá Mandal. This Runn which is about 2 miles broad, extends from the gulf of Cutch right away the whole length of Okhá Mandal, and is only separated from the open sea by a strip of sand hillocks about ⅔ of a mile long and from 200 to 300 yards broad. The Runn therefore causes the Okhá Mandal to be a small peninsula joined to Kattywar by the strip of sand bank above mentioned, close to the village of Madi.

From Topni Ness to Okhá Tidal Station.

(27.) Close to the Runn the ground is very steep and rocky. About a mile further on, it becomes undulating and then tolerably flat right away to Okhá Tidal Station. A great number of coral beds are exposed on the surface between Armra and Okhá Tidal Station; this evidently shows that at a not very distant period it must have been covered by the sea. Okhá Tidal Station is situated at the end of the peninsula and at the point where the gulf joins the sea. I have described it in a former report.

Closed leveling operations at Okhá Tidal Station.

(28.) The leveling operations were completed and closed on the 3 Bench-marks at Okhá Tidal Station and the S. R. T. Gauge bed plate as at Hanstal.

March to Dwárka. Preparation for dismantling the Tidal Observatories.

(30.) Having closed leveling operations I marched to Dwárka and made arrangements with Mr. Rendell for dismantling the stations; and as you had ordered me to do all I could to get complete work from 7th March to 7th May out of Nawanár Tidal Station, and that the instruments at the other observatories should be kept working simultaneously, I arranged that Okhá Tidal Station should be the first dismantled and as soon after the 7th May as possible.

Okhá Tidal Station dismantled.

(33.) Previous to dismantling Okhá Tidal Station, I sent out the Kalassies who remained and some coolies to collect stones to build large mounds or platforms round the Bench-marks and the cylinder which you had ordered me to leave *in statu quo*. By the evening of the 15th of May the whole of the instruments and all the piping, except 50 feet in connection with the cylinder, were put on board the boat which was moved close by for the purpose. The cylinder had been emptied of water and dried out at the bottom (there was no sediment of any description here) and filled with clean dry sand. A thick wooden board closed the top (being secured by bolts and nuts) and an immense mound of stones was raised over it. On the 16th Mr. Rendell sailed for Nawanár to perform the dismantling of Nawanár Tidal Station which was done in exactly the same way as at Okhá.

Okhá Tidal Station as it was left.

(35.) On the day after Mr. Rendell sailed, I left Okhá Tidal Station for Dwárka. All that remained visible of the station being 4 immense mounds of stones. The station was handed over to the charge of the Assistant Resident at Dwárka.

Marched to Rájkot.

(36.) I now marched rapidly from Dwárka to Rájkot and started the office there, and a day or two afterwards went out to Hanstal Tidal Station where Mr. Rendell meanwhile had arrived to dismantle that station. I found he had completed every thing very satisfactorily.

Work during the recess up to date.

(37.) The duplicate sheets of the leveling operations have been completed and computed, but the abstracts cannot be made out until the level of origin at Nawanár Tidal Station above mean level of sea and also that of the closing points at Hanstal Tidal Station and Okhá Tidal Station have been determined. The Tidal diagrams

have all been carefully inked in; the time computations in duplicate have been brought up; and the correction of the diagrams for zero and for time is now in hand. Experiments for Index errors of thermometers and anemometers have also been completed.

Personnel of the Party.

(40.) Mr. Rendell has worked through the whole field season to my entire satisfaction. I have already reported that he is most useful to me in every way connected with the work at the tidal observatories. He has been most painstaking in carrying out everything I wished, and it is mainly owing to his care and vigilance that the work at Nawanár, for the 2 particular months you wished, has been successfully accomplished.

Nursing Dass has worked throughout the season the second level. He is a first rate leveler, a very quick and careful observer and does his work generally to my entire satisfaction and fully bears out the good name he has got from Officers under whom he has previously served.

Damoder Ramchundra, Dhondu Venayek and Shitaram Yeshwant have all worked well at the Tidal Observatories, and give promise of being very useful.

Out-turn of leveling operation.

(41.) The following statement shows the amount of leveling done by the party.

274½ miles on Main line by two independent levelers.
29¼ „ Branch „ „ „
38 Bench-marks, built in masonry platforms, connected.
17 Principal stations connected.
3 Minor stations „
45 Paka points duly inscribed and connected.

Assistance rendered by Political Officers.

(42.) I would again beg to report that I am much indebted to the Political Agents of Cutch and Kattywar and to the Assistant Resident at Dwárka for the assistance they have uniformly rendered me.

General success of the operations; completion of one part of the project.

(43.) In conclusion I think the Party may fairly be congratulated on the general success of the project in having secured both at Okhá and Hanstal Tidal Stations, complete sets of tidal combined with meteorological observations which will compare most favourably with what has been done both in England and America, and in having so far succeeded at Nawanár Tidal Station that the observations taken will be sufficient to evaluate (by differentiating with both Okhá and Hanstal which were working simultaneously) the principal data required.

The leveling operations combined with the tidal observations complete the work necessary for one part of the project and fix the level of about 30 miles of the Runn of Cutch for the season 1874-75, and a repetition of the work some 20 years hence will effectually settle the question of Secular Depression in this peculiar region.

Extract from the Narrative Report—dated 28th September 1875—of Captain W. M. CAMPBELL, R.E., Officiating Deputy Superintendent 2nd Grade, G. T. Survey, in charge Astronomical Party No. 2.

At the date of my last Annual Report, October 1873, I was employed in the reduction of the Electro-Longitude observations, made by Captain Herschel and myself during the preceding season 1872-73.

These reductions were so far complete that I was enabled to give the results of one measurement, that of the arc Bangalore-Mangalore, and subsequently, in time to be included in the General Report, an approximate value of Madras-Bangalore.

(2.) The prosecution of the field operations was suspended in consequence of Captain Herschel's taking furlough in August 1873, and the reductions were also stopped immediately after the submission of my report, because I was unexpectedly obliged to apply for six months furlough to Europe, which was granted.

(3.) I had some months previously been warned that my services would be placed at the disposal of Colonel Tennant for the observation of the Transit of Venus, from a date which was then uncertain.

While I was in England, I was put on duty to assist Colonel Strange in the preparation of the instruments intended for Colonel Tennant's use during the Transit. These formed a very full and handsome equipment, consisting of a 6-inch equatorial, a transit instrument, a photoheliograph, an astronomical clock and quadruple chronograph, all, with the exception of the photoheliograph, ordered from Messrs. Cooke & Sons at so late a date that there was great doubt as to their being got ready in time. I remained on this duty as long as I thought prudent, with a view to joining Colonel Tennant in time for all necessary preparations, and when I left England, the transit instrument and a small part of the equatorial were still in the makers' hands.

(4.) I joined Colonel Tennant at Roorkee on 29th September 1874, some of the instruments had then arrived and the rest came in gradually, all reaching us before the Transit took place. In addition to the special equipment above enumerated, Colonel Tennant had the loan of the new 36-inch theodolite, designed for the Great Trigonometrical Survey by Colonel Strange, which had just arrived from England, and he put it in my charge for the Transit. Our time was very fully occupied in preparations up to the day of the Transit.

(5.) My special duty during the event, was to note the times of all the contacts, and also, while the planet was within the sun's disc, to take chronographic transits of both limbs of the sun and planet over the wires of the theodolite, using the horizontal wires during the early part of the Transit, both sets alternately for a short time about the middle, and the vertical wires afterwards. I found the observation of contact with such an instrument very difficult, because the limbs approached, especially at egress, very slowly, and as practice with the model had shown the probability of the contact being suddenly completed by the formation of the "black drop", the momentary expectation of this lasted over minutes, during the whole of which the motion of the instrument both vertical and horizontal had to be maintained by the tangent screws.

During the Transit I never left the telescope, and secured a large number of the observations of sun and planet described above, which when reduced will afford so many determinations of the relative positions of the two.

(6.) With regard to the 36-inch theodolite, I may remark that it is a magnificent instrument, elaborated in its details to an unusual degree, and as far as I can judge, its performances are excellent. A theodolite, with its large horizontal circle and comparatively short telescope, cannot be a convenient instrument for astronomical work, but I envy the surveyor who may have to use this instrument for triangulation, if his work lies in a moderately level country, *compelling him to resort neither to the tops of high hills nor towers.*

(7.) I left Colonel Tennant in April, and proceeded for a short time to Head Quarters, for the purpose of discussing with the Superintendent the programme of operations during the ensuing field season, when it is intended that I should go on with the Electro-Longitude observations with Captain Heaviside, R.E. as my colleague. I then proceeded by Calcutta and Madras to resume my proper duty at Bangalore.

(8.) At Calcutta I had several consultations with Mr. Schwendler, Electrician of the Government Telegraph Department, on the subject of the electrical arrangements of our chronographs and the electrical portion of our work generally. I found him extremely obliging, and ready to assist me in undertaking experiments as to the chronographic arrangements under discussion, to which I shall refer again. I also obtained from him some useful general information, with reference to our operations.

(9.) I was engaged for nearly a fortnight at Madras in forwarding the determination of the difference of longitude between Roorkee and the Madras Observatory by the electric telegraph, which was required to enable Colonel Tennant to reduce his Transit of Venus observations.

(10.) After arrival at Bangalore it was a matter of some time to pick up the threads of the work, which had been in abeyance for more than a year and a half, and was of so novel a kind, that no cut and dried plan of procedure had been adopted. At first I had no assistance beyond that of my native writer and but little progress in the reduction was practicable. Since my reinforcement by Messrs. Keelan and Bond, the reductions have made rapid progress and are now nearly complete.

(11.) My own time has been very much occupied with the instrumental equipment. I would refer to my last report, and that of Captain Herschel, on this subject, which contain detailed descriptions of the equipment and the performances of its various parts. 1st, one of the transit telescopes was condemned, as being to a certain extent untrustworthy, owing to uncertainties in its line of collimation. 2nd, the electric arrangements of the chronograph were bitterly complained of by both of us, as giving endless trouble and anxiety to such a degree that up to the close of the season's work we could never safely reckon on getting through a night's observations without a hitch.

(12.) I first turned my attention to the faulty Transit, encouraged in the work by the fact that a similar failing in the Transit circle of the Cambridge Observatory, which was under investigation when I wrote my last report (*vide* para 20), had been since traced to bad soldering and corrected (*vide* Monthly Notices of Royal Astronomical Society for February 1875, page 188). The idea of such a cause, when suggested to my mind, commended itself as that which would best explain the effects we had observed, indeed it at once made clear what before was obscure. My first step was to carry out the process described as contemplated in my last report and by a little filing the reversal of the object half tube (*i.e.* revolution on its own axis through 180°) at its connection to the axis, was rendered possible.

Half an hour's observation of collimators then showed that the fault was in that part, because the errors previously observed remained identically the same, except that their signs were changed.

(13.) I then took the tube to Madras and showed it to Mr. Doderet, the Mathematical Instrument Maker to Government. When we examined it with a magnifying glass, signs of yielding round the base of the tube became apparent, and farther search showed that the tube had been spliced, in order probably to make it correspond to the focal length of the object glass after the latter had been ground. The existence of such patching must be considered sufficiently discreditable to makers of the rank of Messrs. Cooke & Son, and it was also imperfectly and clumsily executed. Very little doubt remained as to our having found the seat of the mischief, and Mr. Doderet, at my request, immediately took steps to strengthen the splicing and make it effectual.

(14.) When I received the tube from Madras and put the telescope through exactly the same course of observations as before, I found that the fault, if not absolutely, was practically eliminated, as I failed to discover any certain indication of what had previously been most gross quantities.

This result must be considered very satisfactory with regard to our future observations, and moreover, having now a clear knowledge of the nature of the old fault, it may be possible to amend the method by which the collimation and level corrections for the instrument were deduced during season 1872-73.

(15.) I next attacked the arrangements of the chronograph. As already remarked I had some consultation at Calcutta with Mr. Schwendler on this subject.

My object was, 1st, to get rid of the induction coils, involving the troublesome Bunsen Batteries, and frictional electricity, and 2nd, to throw aside also if possible all chemically prepared paper. I had several alternative schemes in view.

1st.—To record by lines traced on prepared paper by means of electric currents.

2nd.—To prick holes in the paper by mechanical means put in action by electric currents.

3rd.—To use pens drawing continuous lines, the signals being recorded by sudden jerks to one side caused by electric currents.

(16.) The arguments in favor of the first were theoretically greater instantaneity of signal record, and no change being required in the parts of the chronograph for its adoption. Against it, the necessity of prepared paper, very similar to what we had already found so objectionable, and the probable necessity for strong battery power. It was to perfect this method that Mr. Schwendler so kindly undertook to execute experiments.

The second method I was familiar with, being the same as that of Colonel Tennant's chronograph, and I knew it to be perfectly trustworthy and simple, but on the other hand the alteration of our chronographs to suit it would have been troublesome.

The last method I was already familiar with by description, as it is that generally used in America, and at Madras I had the opportunity of seeing it in practice in a small chronograph of Mr. Pogson's, the action of which was so very certain and satisfactory that I at once decided on adopting the principle if possible.

(17.) On examination of our chronographs I found the changes required would be very simple and easy, and our own apparatus contained the necessary parts of any importance, *viz.*, the electromagnets of the relays, which the adoption of the new method would throw out of use. I accordingly drew up a design which Mr. Doderet executed, with in some respects perfect success, and he has now in his hands an amended design, which I see no reason to doubt will prove quite satisfactory in every way.

(18.) The first attempt failed, because I was striving to obtain the double record of clock and observer (or two clocks) by means of only one pen, which would have had the great advantage of doing away with "style (or pen) equation".

After a good deal of experiment I was obliged to abandon this, finding that in order to obtain a satisfactory record, a somewhat radical change in our present means of producing the signals (breaking and making circuit) would be necessary, which I did not think the object justified me in attempting with the time and means at my disposal. The present design comprises two pens following each other on the paper, just as the styles did formerly.

My confidence in its being found to answer, is I think justified by the single record, already obtained from a similar pen, being as good as one could wish. The only change in the chronograph is, that the ebonite plate carrying the styles has been taken off the carriage, (see my last report para. 24) and a larger plate of wood substituted, on which are fitted two electro-magnets (taken from our old relays) and the pens, which project over the barrel just as the styles did, and trace exactly similar spiral lines.

(19.) This method does away with all the objectionable features of the old arrangement, and is as simple as can be easily imagined. There may be a slight loss of accuracy, but I doubt even this, and if it does occur it must be of the irregular kind which can cause no deterioration in the final results.

It has also the advantage of economy in saving expensive chemicals, as well as by reducing the amount of apparatus carried about. Lastly, a great deal may be often gained by the two observers exchanging telegraphic information, in doing which Captain Herschel and I constantly lost time by our inability and (common to all beginners in the art of signalling) to read as fast as we could signal.

With the pen recorder the message may be written on the chronograph and read off at comparative leisure.

(20.) There is another point in the equipment which has been much improved since our last field work, *viz.*, the collimators.

Those belonging to the Transits have only recently been received from England and are in every way superior to the ones formerly used, and they have an ingenious feature in their construction, by which any movement of the instrument on its pier (which must take place owing to difference of expansion and contraction under varying temperatures) is confined to the direction of the axis. This is likely to prove valuable, because with our field observatories the collimators are necessarily placed on pillars outside, without any adequate protection either from the heat of the sun or the cold at night.

(21.) The point is of importance chiefly with reference to the use of the collimators as meridional marks, which they never strictly are, because the deviation of the Transit instrument is determined independently every night. But if the collimators are appreciably stable, as I expect will prove to be the case (and as to which their mutual observations afford most searching evidence) they will provide the means of combining all the observations for deviation at a station, in order to get the error for each night. Our former experience shows that this, if obtainable, will prove a great advantage.

Extract from the Narrative Report—dated 23rd November 1875—of W. H. COLE, ESQ., M. A., Officiating Deputy Superintendent 3rd Grade, G. T. Survey, Officiating in charge Computing Office.

I have the honor to lay before you the report on the work performed by the Computing Office between the 1st May 1874—up to which date the last report details it—and the 1st October of this year, that is, for a period 5 months in excess of that usually reported on. This change is due to your having recently directed that Executive Officers should bring the narratives of their operations up to the end of the recess season, succeeding the field season to which they refer. I draw your attention to it, because were it not borne in mind, the out-turn of work I am about to detail would appear out of proportion to that of previous years.

CALCULATING BRANCH.

Final Reduction of the Triangulation.

(3.) The attention of this Branch has, whenever opportunity offered, been steadily directed to the final reduction of the triangulation of India and the publication of the results, and considerable progress has now been made. Of the five large sections into which you have divided the triangulation west of the Meridian of 89° three are now in hand, and I will endeavour to give you a general idea of the progress that has been made with each before stating the work of the Office in detail.

North-West Quadrilateral.

(4.) This division of the triangulation which extends over an area of about 475,000 square miles was in a very advanced state when reported on last year. All the principal triangulation had been reduced

Calculating Branch—(Continued).

and the results passed through the press, and one of the Synoptical Volumes—which give only such data of each series as are required for practical purposes—had been published, *viz.*, Volume I, or the Great Indus Series. Since that date four more Synoptical Volumes have been completed and published, *viz.*,

Vol. II. or the Great Arc Series, Section 24° to 30°.
Vol. III. „ Karáchi Longitudinal Series.
Vol. IV. „ Gurhágarh Meridional Series.
Vol. V. „ Rahún Meridional Series.

There still remain three series to complete this section of the triangulation, the Jogí-Tilá Meridional, Sutlej River and North-West Himalaya. The two former are in a very advanced state and will probably together form Volume VI of the Synoptical Volumes. I hope to send them to the binder in the course of two or three more weeks. The North-West Himalaya Series is ready for the press, but has to give place to other subjects more urgently required. It will be some months before it can be published; but nothing now remains to be done in connection with it by this branch of the office further than to superintend it through the press. It will be accompanied by several charts, most of which are drawn but have not yet been photozincographed.

South-East Quadrilateral.

(5.) This section of the triangulation of India, which is contained between the Meridians of 77° and 89° and the parallels of 17° and 24°, is that which you directed should be reduced second in order. Neglecting the two short triangulations of the South Párasnáth and South Malúncha Series, which were not executed with first class instruments, the Quadrilateral contains six chains of triangles forming three mutually dependent circuits. At its north-west corner it units with the N. W. Quadrilateral, the side Kámkhora to Bhaorása of the Sironj Base-line figure being common to both. The length and position of this side having been finally determined in the reduction of that Quadrilateral were considered invariable. At each of the other corners are base-lines, *viz.*, those of Calcutta, Vizagapatam and Bider. Its reduction necessitated finding the values of 831 unknown quantities, which should satisfy 292 equations of condition. 277 of the equations were however of such a form that an equal number of unknown quantities were readily eliminated and the undertaking was thus reduced to finding 554 unknown quantities to satisfy 15 equations, subject to the usual condition that the sum of the squares of the several quantities multiplied by their respective weights should be a minimum. Although the method of reduction was the same as that adopted for the North-West Quadrilateral, the experience gained from the latter has suggested many slight modifications in the details of the computations which have led to a considerable saving of labour. This has been further lightened to a very marked extent by the employment of Arithmometers, and I have now the satisfaction of reporting that not only has the principal triangulation been finally reduced and prepared for publication, but also that a large amount of secondary triangulation connected with it is in a far advanced state; that of the Great Arc, Section 18° to 24°, the Calcutta Longitudinal Series and the Coast Series is almost finished and only needs to be arranged for publication; that of the remaining series is in an advanced state. Thus in a few months nothing will remain but to pass the data through the press.

The following table contains the facts of computation of the Principal triangulation. In column (1) the 15 equations, which remained after the elimination of the unknown quantities above mentioned, are numbered in the order in which they were arranged for solution. Of these the first six are side equations, five of them being between base-lines, the measured lengths of which, have, for the purposes of reduction, been assumed as errorless. The sixth is a circuit equation. The remaining nine are all circuit equations in Latitude (λ) Longitude (L) and Azimuth (A). The circuits are shown by the letters in column (2) which have reference to the diagram. In column (3) are the absolute terms of the equations, or the errors which had to be dispersed between the base-lines or in the circuits. It should be stated that the terms in which the linear errors, *viz.*, those of the first six equations, are here expressed differ from those employed for the N. W. Quadrilateral which will be found tabulated on page 54—a of your report for 1870-71, the former being differences in the 7th place of logs and the latter similar differences divided by *Modulus* × *sin* 1″: the change is due to a simplification in the manner of expressing the co-efficients of the unknown quantities. The simultaneous solution of the equations involved finding the values of an equal number of indeterminate factors, and column (4) exhibits the accuracy with which this solution was performed, the quantities shown in it being obtained by substituting the deduced values of these factors in the normal equations. With the aid of the indeterminate factors, values of the angular errors involved in the equations of condition were found, at first to 5 places of decimals of seconds, and afterwards reduced to 3 places. These values being substituted in the equations produce the quantities given in columns (5) and (6), and their accordance with the quantities in

Calculating Branch—(Continued).

column (3) affords the second test which was applied to the accuracy of the calculation. These tests having been considered satisfactory the angular errors to 3 places were introduced into the computations and the corresponding corrections made: the last column exhibits the residual discrepancies which then remained.

With regard to the first six equations it should be stated that the calculations of the triangles have been made with tables of logarithms to 7 places of decimals only, an 8th place being obtained by interpolation, yet the discrepancies are at most only 4 in the 8th place of logs, and two of them cancel if the triangulation is considered continuous from the side Kámkhera to Bhaorasa *vid* Calcutta, to Vizagapatam. Furthermore, if a complete circuit is made starting from the side Kámkhera to Bhaorasa and carrying the calculation of the triangles round the whole periphery of the Quadrilateral, the value of the side of origin is reproduced identically to the eighth place of decimals of logs. The largest discrepancies in latitude and longitude still remaining are "005, or about 6 inches.

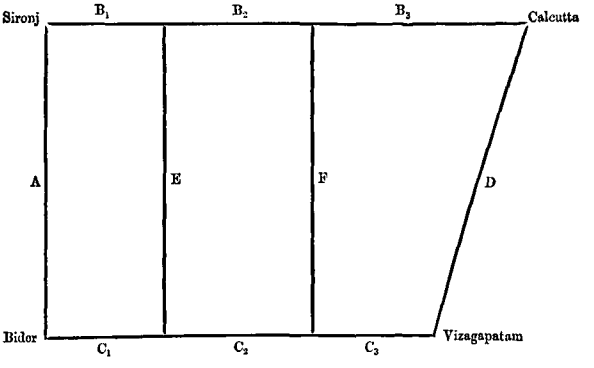


Table of the facts of computation.

No. of Equation		Triangulation involved	Value of circuit error: Before reduction	By substitution of "indeterminate factors"	By substitution of deduced angular errors: As computed to 5 decimals	By substitution of deduced angular errors: On contraction to 3 decimals	Residuals after correcting the angles
(1)		(2)	(3)	(4)	(5)	(6)	(7)
1	In Side	A	− 16·44	− 16·439	− 16·441	− 16·439	0·0
2	In Side	$C_1-(B_1+E)$	− 54·86	− 54·860	− 54·859	− 54·864	+ 0·2
3	In Side	$B_1+B_2+B_3$	+ 42·5	+ 42·500	+ 42·500	+ 42·501	− 0·4
4	In Side	$C_1+C_2+C_3$	− 21·29	− 21·291	− 21·289	− 21·292	0·0
5	In Side	D	− 6·93	− 6·932	− 6·931	− 6·932	+ 0·4
6	In Side	$(E+C_2)-(B_2+F)$	+ 31·9	+ 31·900	+ 31·901	+ 31·902	+ 0·2
7	in λ	$(A+C_1)-(B_1+E)$	+ 0″·050	+ 0″·0500	+ 0″·0500	+ 0″·0500	− ″·002
8	„ L	Ditto	− 0·214	− 0·2140	− 0·2140	− 0·2139	− ·005
9	„ A	Ditto	+ 0·212	+ 0·2120	+ 0·2119	+ 0·2117	·000
10	„ λ	$(E+C_2)-(B_2+F)$	− 0·216	− 0·2160	− 0·2160	− 0·2160	− ·004
11	„ L	Ditto	+ 0·203	+ 0·2030	+ 0·2030	+ 0·2029	·000
12	„ A	Ditto	− 4·968	− 4·9680	− 4·9682	− 4·9682	+ ·008
13	„ λ	$(F+C_3)-(B_3+D)$	− 0·142	− 0·1420	− 0·1420	− 0·1419	− ·005
14	„ L	Ditto	+ 0·239	+ 0·2390	+ 0·2390	+ 0·2388	·000
15	„ A	Ditto	− 3·888	− 3·8880	− 3·8880	− 3·8881	− ·005

In 7th place of Logs. / Natural Numbers

North-East Quadrilateral.

(6). As the reduction of the principal triangulation of the South-East Quadrilateral approached completion, I was enabled to make a commencement with the third section of the triangulation,

Calculating Branch—(Continued.)

known departmentally as the North-East Quadrilateral. It is bounded on the west by the Great Arc Series, Section 24° to 30°, on the south by the Calcutta Longitudinal Series and has in its eastern and northern periphery, the Calcutta Meridional and North-East Longitudinal Series. It contains twelve series, forming eleven circuits and its reduction will prove a more serious undertaking than that of any of the other divisions. At present only the circuit errors are in course of calculation, but this preliminary computation will shortly be complete and then the reduction itself can be taken in hand.

Other calculations.

(7). In addition to the calculations I have already described a good deal of assistance has been given to Captain Heaviside in preparing and passing through the press the results of the Pendulum Operations. Captain Trotter has also received much aid; the computation of the entire mass of the observations made by him, while he was attached to the Yárkand Mission having been performed by this Office and the results tabulated for publication in his report. A quantity of miscellaneous work has also been performed which is briefly summed up elsewhere.

Arithmometers.

(8). I noticed above the great advantage which had accrued from the use of Arithmometers, instruments which were introduced in to the office by yourself several months ago. Some of the computations which formerly occupied a pair of computers a fortnight or three weeks can with their aid be completed in four or five days. They are almost invaluable and would be quite so if more care was bestowed on their construction. They are of foreign manufacture and the several parts appear to be made in the gross, and then to be roughly put together; thus many of them soon get out of order and make mistakes. Were they carefully constructed as they would be by English mechanics, the principle on which they are designed is such that it seems impossible they should commit errors; as their manufacture is protected by a patent the desired improvement is not I fear likely to be effected.

Another aid to the computers, recently introduced into the office, is Crelle's Rechentafeln, a book of products of all numbers from 1 to 999. In this case foreign labour has the advantage over English; for it has produced at a cost of only sixteen shillings a most useful book, the labour of compiling which must have been enormous.

(9). The details of the ordinary calculations are as follows :—

Angle Books, indexed	467 vols.
Abstracts of Angles, copied and compared	600 angles.
Zero and general means computed	600 „

Computations in Duplicate.

Principal Triangulation	Weights computed	383
	Spherical Excesses computed	277
	Simple Quadrilaterals reduced	32
	„ Polygons „	32
	Compound Figures „	11
	Auxiliary reductions made	75
	Triangles computed	537
	Lats. Longs. Azimuths computed	750
	„ „ „ corrected (after S. E. Quadl. grinding)	140
	Heights computed	170
	„ examined, corrected and adjusted ...	630
Secondary Triangulation	Traverses computed	18
	Ray Traces computed	6
	Triangles adjusted and computed	2,400
	Heights computed	12
	Latitudes, Longitudes and Azimuths computed	1,100
Explorations	Latitudes	30
	Heights by Boiling Point	130

(10) The work performed in connection with the Typographic and Photozincographic presses, is detailed below.

Calculating Branch—(Continued).

For Typographic Office.

Synopses of the operations &c.	Pages compiled and printed.	Compiled, but not yet put to press.
Azimuth Table, Jogí-Tilá and Sutlej Series	14	
Alphabetical Lists of Gurhágarh, Rahún Sutlej and Jogí-Tilá Series	105	
Errata and Contents, Gurhágarh, Karáchi, Rahún, Great Arc (24°-30°)	11	
Note to Great Arc Final Chart	2	
Co-ordinates and Descriptions &c., of N. W. Himalaya Series, comprising 39 square degrees		The whole
Numerical and Alphabetical Lists of Principal Stations, Descriptions of Principal Stations of the Series comprised in the S. E. Quadrilateral	30	The remainder
Triangles Principal and Secondary of the Arc, Calcutta and Coast Series		About 80 pages which are half ready

For Vol. (S. E. Quadrilateral).

Lists, Descriptions of Stations, Observed Angles, Reduction of Figures and Principal Triangles

R. Calcutta Longitudinal Series	42	(to end of figs.)
Great Arc (18°—24°)	18	(„ △s)
Jabalpúr	56	(„ figs.)
Biláspúr	86	(„ „)
Coast	4	(„ lists)
Bider	40	(to near end of ∠s)

To end of heights above Mean Sea Level

Besides the above, the auxiliary reductions of the figures of the E. Coast Series and of a portion of the Biláspúr Series, including about 20 pages of printed matter, have been compiled but not yet put to press. Some progress has also been made in setting up the azimuthal observations appertaining to the South-East Quadrilateral for the press.

Other compilations for departmental and general use.	Compiled and printed.
Book of Routes in N.W.P., Himalayas &c., ...	34 pages
Data for Rangir Series Charts Nos. 1, 2, 3	13 „
Data for Biláspúr Series Chart, (S. Section) (1872-73)	8 „
Data for E. Frontier Series „ (1873-74)	1 „
Appendices to Vol. II	23 „

For Photozincographic Office.

Final Charts.	Compared or examined.
Karáchi Series	2
Great Arc Series (24° to 30°)	1
Gurhágarh „	2
Rahún „	2
N. W. Himalaya Series	2
Jogí-Tilá Series	1
Sutlej „	1
Total	11

Preliminary Charts.	
Madras Longitudinal and Mangalore Meridional Series (1871-73) ...	1
Biláspúr Series (S. Section) (1872-73)	1
Rangir „	3
Assam Valley Survey (1869-74)	1
„ „ „ (1873-74)	1
Bombay Island Survey	1
Total	8

For Office use.	
Triangulation of the South-East Quadrilateral	1

Calculating Branch—(Continued).

Instrumental Work.

(11.) Observations for time were taken on 20 occasions during the year for the purpose of shewing mean time and rating chronometers. Meteorological Observations were made in the Dehra Observatory on every day throughout the year, and the results were reduced and communicated month by month to the Reporter on Meteorology N. W. Provinces. A table of monthly means is as usual appended to this report. The large self-registering Anemometer referred to in last year's report was put into working order in January last, and a record has been since kept of the hourly velocity and direction of the wind. The winds in the Dún are so light that they often fail to turn the fans which move the direction pencil and this part of the record although it has been always tabulated, has not been made any use of at present. To do so would necessitate a careful weeding out of all hourly velocities below a certain fixed minimum. As yet only mean hourly velocities, irrespective of direction have been deduced for each month, an abstract of which follows that of the Meteorological Observations. It is remarkable how closely the curves formed from these data resemble one another.

Protection of Stations.

(12.) The preservation of the Principal Stations of this Survey has been as usual steadily kept in view, and much correspondence has in consequence been entailed. Replies to about 350 letters on this subject were drafted by Mr. C. Wood under your direction, and about 40 letters addressed to district officers who had failed to submit their annual reports on the stations placed under their charge. Modern changes in the boundaries of districts have caused some difficulty in ascertaining what stations fall within each. Since last reporting 16 more districts have been finally settled, making in all 307 districts of which the lists are now complete. The check lists now include 2,700 stations.

Miscellaneous.

(13.) Several duties of a miscellaneous character have also been performed by this branch of the office which may be briefly summarised as follows:—Reduction of barometer readings; computation of humidity and observed refractions on the Jogí-Tílá Series for Appendix No. 3 to Vol. II:—Preparation of Appendices Nos. 2, 4 and 5 to Vol. II:—Examination and arrangement of four Synoptical Vols. for the binder:—Translation of two Explorers' route survey field books:—Alphabetical lists of Indian proper names prepared for departmental issue:—New tables (Auxiliary) and a new form constructed to facilitate the computation of circumpolar star observations for azimuth:—Data collected for discussion as to the advisability of giving the observed azimuths in the S. E. Quadrilateral effect in the final reduction of the triangulation:—Circuit errors of the Kashmir triangulation and North-West Himalaya secondary triangulation determined and dispersed:—Effect of the difference in the values of the earth's axes as adopted by Everest and Clarke on differences of latitude, longitude and azimuth computed for arcs of various magnitude:—Elements of the Bombay Island Survey, executed in 1865-66, prepared for publication:—Differential latitudes and longitudes examined for the new edition of the Turkestan Map:—Captain McCullagh's and Lieutenant Harman's leveling records examined and reported on:—'Errors of mean square' of latitude, longitude and azimuth at the terminal stations of the right and left hand branches of the circuits of the N. W. Quadrilateral, computed from the origin of each circuit. Twenty-nine officers have been supplied with data. Forms for departmental use have been issued to 96 officers, and 776 parcels containing maps, charts, &c., were booked and despatched. Four candidates for employment in the Junior Branch were examined and three instructed in departmental computations; and papers supplied for the examination of six other candidates, besides several other duties which need not be enumerated here.

TYPOGRAPHIC BRANCH.

(14.) The work performed during the 4 years ending 1st May 1874, and the 17 months, 1st May 1874 to 1st October 1875, is concisely stated thus.

	1870-71	1871-72	1872-73	1873-74	1874-75 (17 months)
Pages composed, ...	819	1,143	1,420	1,220	1,868= 1,319 per annum.
Do. printed, ...	234,828	241,348	273,157	388,420	527,916=372,647 ,,

Typographic Branch—(Continued).

The total pages composed in the 17 months under report may be subdivided thus,

For volumes of the G. T. Survey, ...	1402
„ Route Book, ...	35
„ Charts, Memos, &c., ...	306
„ Annual Report, ...	125
Total ...	1868

DRAWING BRANCH.

The work executed by the Drawing Office is exhibited in the table which follows this report. Some very important maps have been prepared there during the past year; those of most general interest are the 3rd Edition of the map of Turkestan, compiled under your own superintendence; the map to illustrate the reports on Sir Douglas Forsyth's Mission to Yárkand and other maps relating to Trans Frontier explorations, the compilation of which is due to Captain Trotter.

PHOTO-ZINCOGRAPHIC BRANCH.

The work from 1st May 1874 to 30th September 1875 is shewn below under the heads of Maps, Charts, Diagrams and Forms.

Maps.

SUBJECT.	When published.	No. of parts.	No. of copies printed.
Prints of maps published in former years	...	40	1,341
Guzerat, sheet No. 8	May 1874	1	113
Ditto No. 9	„ „	1	105
Index to Dehra Dún Survey	September „	1	481
Kattywar Survey, degree sheet No. VI	October „	1	107
Ditto No. VII	„ „	1	150
Index to Kattywar Survey	„ „	1	468
Route map for the W. Himalayas &c., ...	„ „	1	473
Chamba Map	November „	4	22
Index to Kumaun and Garhwál Survey	„ „	1	460
„ Guzerat Survey	„ „	1	426
Kumaun and Garhwál, sheet No. 25, skeleton ...	„ „	1	105
Dehra Dún Tea Company's Plantation, sheet No. 1 ...	„ „	1	75
Ditto No. 2 ...	„ „	1	76
Guzerat Survey, sheet 80, section 3	December „	1	135
Jaunsár Map	„ „	1	22
Eastern Turkestan	„ „	2	478
Plan of Landour Bazar	January 1875	1	53
Map illustrating Trans-Himalayan Explorations during 1872	„ „	1	466
Index to Mussooree and Landour Survey	February „	1	28
Town and Cantonment of Rájkot	„ „	2	83
Map illustrating Trans-Himalayan Explorations during 1873	„ „	1	491
Kattywar Survey, sheet No. 35	March „	1	133
Guzerat „ „ 80, section 2	„ „	1	110
„ „ „ „ „ 11	April „	1	110
„ „ „ „ „ 9	„ „	1	135
„ „ „ „ „ 7	„ „	1	105
„ „ „ „ „ 1	„ „	1	127
Kattywar Survey, sheet No. 33	„ „	1	147
„ „ „ 32	May „	1	133
Mussooree and Landour Survey, sheet No. 15, skeleton	„ „	1	44
Turkestan Map, sheet No. 1 (3rd edition)	„ „	1	263
„ „ 2 „	June „	1	227
„ „ 3 „	„ „	1	284
„ „ 4 „	„ „	1	273
Kattywar Survey, sheet No. 34	July „	1	154
Kumaun and Garhwál, sheet No. 33, skeleton ...	August „	1	177
„ „ „ 12 „	„ „	1	156
„ „ „ 9 „	„ „	1	156
„ „ „ 22 „	September „	1	61
„ „ „ 38 „	„ „	1	167
„ „ „ 31 „	„ „	1	159
Guzerat Survey, sheet 80, section 13	„ „	1	107
„ „ 8	„ „	1	106
„ „ 5	„ „	1	105
Dehra Dún and Siwalik No. X } For Forest Department	„ „	1	132
„ „ „ XIX }	„ „	1	137
„ „ „ XX }	„ „	1	108
	Total ...	92	9,974

Photo-zincographic Branch—(Continued).

Charts.

Besides the foregoing 28 Blue prints were issued and several Silver prints were prepared on the scale of the Indian Atlas for the use of the Engravers.

SUBJECT.	When published.		No. of parts.	No. of copies printed.
Madras Longitudinal and Mangalore Meridional Series (1871-73) Numerical	July	1874	2	67
Assam Valley Triangulation (1872-73) Numerical	August	,,	2	67
Karáchí Longitudinal Series, Chart No. 1 Final	,,	,,	1	373
,, ,, 2 ,, ...	,,	,,	1	371
Rangír Meridional Series, Chart No. 3 Numerical ...	,,	,,	1	65
,, ,, 1 ,, ...	September	,,	1	65
Biláspúr Series, season 1872-73 (S. section) ,, ...	,,	,,	1	65
Brahmaputra Series, season 1873-74 ,, ...	,,	,,	1	65
Great Arc Series, (Sec: 24°-30°)Final ...	,,	,,	1	384
Gurhágarh Meridional Series, Chart No. 1 Final ...	October	,,	1	367
Eastern Frontier Series, season 1873-74 Numerical ...	November	,,	1	65
Rangír Meridional Series, sheet No. 2 ,, ...	,,	,,	1	65
Gurhágarh Meridional Series, Chart No. 2 Final ...	December	,,	1	375
Malabar Minor Series, season 1873-74 Numerical ...	January	1875	1	65
Assam Valley Survey, season (1869-74) ,, ...	,,	,,	1	67
,, ,, (1873-74) ,, ...	,,	,,	1	65
Bangalore Meridional Series (Great Arc), season 1873-74 Numerical	February	,,	1	70
Bombay Island Survey Numerical ...	,,	,,	1	65
Rahún Meridional Series, Chart No. 1 Final ...	March	,,	1	361
N. W. Himalaya Series No. 1 Final ...	,,	,,	1	370
,, ,, 2 ,, ...	,,	,,	1	372
Rahún Meridional Series, Chart No. 2 Final ...	April	,,	1	372
Jodhpúr Series, season 1873-74, Numerical ...	,,	,,	1	70
	Total ...		25	4,271

Diagrams.

SUBJECT.	When published.		No. of copies printed.
Plates to illustrate Volumes II, III, IV, V, VI, of the G. T. Survey, and other diagrams.	July	1874	50
	August	,,	382
	October	,,	46
	November	,,	1156
	December	,,	680
	February	1875	4
	April	,,	390
	May	,,	370
	June	,,	190
	July	,,	736
	August	,,	402
	September	,,	837
	Total, ...		5,243
Professional and Office Forms.	1874-75 (17 months)		34,310

Photo-zincographic Branch—(Continued.)

7,536 Maps and 4,446 Charts were issued during the year. The forms are always expended as fast as printed. Contrasting the work performed since 1870-71 we have,

Year	Maps	Charts	Diagrams	Forms
1870-71	6,465	839	13,205	10,482
1871-72	10,131	1,375	4,937	13,655
1872-73	6,910	2,206	12,055	12,549
1873-74	9,207	2,027	3,557	28,125
1874-75 (17 Months)	9,974	4,271	25,43	34,310

An abstract of the work executed during the past five years stands as follows.

SUBJECT.	Number of Prints.				
	1870-71	1871-72	1872-73	1873-74	1874-75 (17 months)
Maps, Charts and Diagrams, ...	20,509	16,443	21,171	14,791	19,488
Forms, ...	10,482	13,655	12,549	28,125	34,310

In conclusion I must express my thanks to the several members of the office for their cordial co-operation in, and conscientious discharge of its duties. Where all have worked so well it seems almost invidious to single out any for especial commendation. I cannot however refrain from doing so in one instance at least. Mr. Wood has been associated with me in the same office for nearly nine years; but I have never hitherto had an opportunity, similar to the present, for placing on record my high opinion of his services and it is with pleasure that I now avail myself of it to state that I consider them very valuable. His duties are of a nature constantly requiring the exercise of no small patience and perseverance but his energies never seem to flag and his knowledge and experience are often of the greatest service.

Mr. Todd has done excellent work while attached to this office, and while congratulating him on his restored health, I cannot but regret that it necessitates his return to field duties and thus deprives the office of his services.

Mr. Peychers has proved himself exceedingly useful and deserves every commendation. Besides taking his regular share of the work, a good deal of the final supervision of press proofs has to be entrusted to him and in this he has been of much assistance to me.

Mr. Keating has become fairly well acquainted with the processes of computation and works industriously.

Baboo Gunga Pershad has discharged his duties in the same exemplary manner he always has done and deserves that I should add my testimony to that so frequently expressed by Mr. Hennessey as to his efficiency. Baboo Cally Mohun has also gained my approbation by the intelligent interest he takes in his work. On more than one occasion he has made suggestions with reference to the calculations which have led to a diminution of labour. Baboos Kally Coomar, Gopal Chunder and Tarapodo have worked with their accustomed diligence, and the other computers have given me every reason to be satisfied with them.

In the Drawing Office Mr. Atkinson has continued to conduct his duties as successfully as heretofore, and although the loss of his two best men, Sheik Saidudeen and Goormukh Sing, has for a time considerably diminished the power of his office, he is doing his best to train up others to supply their places.

In the Photo-zincographic Office Mr. Ollenbach is as hard working as ever. I am glad to observe that he now throws more of the manual labour on his subordinates, devoting his own attention to

supervision of their work, and the out-turn is very satisfactory. Mr. Dyson deserves great credit for the excellence of his negatives. I could wish that his assistants Dempster and Lloyd made more rapid progress under his instruction, but the art of Photography is not learnt in a day, and with more practice no doubt they will become more proficient.

Mr. O'Connor in the Printing Office has worked very industriously and the out-turn of work has been fully as great as the office was capable of. He was at one time somewhat lax in the discipline he maintained among his subordinates, I am glad that he has done his best to correct this fault.

Mean Velocity in miles of the winds which blew at Dehra during 8 months of 1875 for each hour of the day.

Civil Hours.	February.	March.	April.	May.	June.	July.	August.	September.
0 to 1	2·27	3·13	3·75	3·14	2·67	1·41	0·59	0·90
1 „ 2	2·19	2·68	3·00	2·71	1·97	1·52	0·66	0·74
2 „ 3	2·39	2·23	2·54	2·36	2·03	1·48	0·66	1·10
3 „ 4	2·31	2·03	2·32	1·86	1·77	1·48	0·38	0·83
4 „ 5	1·96	1·97	2·11	1·71	1·63	1·00	0·14	0·57
5 „ 6	2·58	2·10	1·86	2·07	1·70	1·07	0·28	0·50
6 „ 7	2·08	1·87	1·75	1·79	1·33	0·62	0·14	0·43
7 „ 8	1·81	1·68	1·63	1·96	1·10	1·07	0·34	0·40
8 „ 9	1·96	1·67	1·86	2·68	1·00	1·00	0·69	0·70
9 „ 10	2·19	1·90	2·78	2·78	1·43	1·38	0·79	1·20
10 „ 11	2·46	2·72	3·96	3·11	2·17	1·52	1·21	1·53
11 „ 12	2·31	2·93	4·11	3·96	2·07	1·52	1·66	1·53
12 „ 13	3·11	3·85	4·86	3·79	2·33	1·83	1·33	2·03
13 „ 14	3·07	3·88	4·93	4·18	3·07	2·07	1·90	2·40
14 „ 15	3·22	4·23	5·28	4·89	3·00	1·59	1·57	2·33
15 „ 16	3·08	3·83	4·86	4·43	2·90	1·59	1·37	1·47
16 „ 17	2·50	3·32	4·59	3·89	2·20	1·34	1·20	0·97
17 „ 18	1·50	1·98	3·34	3·68	1·30	0·90	1·07	0·57
18 „ 19	1·12	1·19	1·72	3·25	0·70	0·28	0·66	0·47
19 „ 20	1·46	2·32	2·31	3·18	1·57	0·41	0·62	0·60
20 „ 21	2·54	2·94	3·14	3·75	2·47	0·45	0·76	0·90
21 „ 22	2·08	3·00	3·72	3·36	2·27	0·69	0·55	0·77
22 „ 23	2·42	3·10	3·72	3·57	2·47	1·17	0·90	0·87
23 „ 24	2·52	3·23	3·14	3·50	2·27	1·03	0·86	1·07
Sums, ...	55·13	63·78	77·26	75·60	47·42	28·42	20·33	24·88
Averages, ...	2·30	2·66	3·22	3·15	1·98	1·18	0·85	1·04

MONTHLY Meteorological results taken from the Register kept at the Office of the Superintendent G. T. Survey of India, Dehra Dún.

YEAR & MONTH.	BAROMETER.						HYGROMETER.				THERMOMETER.							RAIN.		WIND.	CLOUD.	
	h. m. At 9 30 A.M.			h. m. At 3 30 P.M.			h. m. At 9 30 A.M.		h. m. At 3 30 P.M.		Dry Bulb.					Wet Bulb.						
	Highest.	Lowest.	Monthly mean.	Highest.	Lowest.	Monthly mean.	Monthly mean Temperature of Dew point.	Monthly mean Humidity.	Monthly mean Temperature of Dew point.	Monthly mean Humidity.	Max: in Sun's rays.	Min: on grass.	Max: in air.	Min: in air.	Monthly mean in air.	Max: wet.	Min: wet.	Monthly mean wet.	No. of days it fell.	Fall in inches.	Average direction.	h. m. At 9 30 A.M.	h. m. At 3 30 P.M.
1874.	in.	in.	in.	in.	in.	in.	°		°		°	°	°	°	°	°	°	°					
January	27·989	27·681	27·814	27·883	27·617	27·730	43·2	·716	44·3	·531	84·5	28·8	71·2	31·8	53·3	63·5	27·5	44·5	4	1·46	W.	5	5
February	·873	·417	·736	·784	·329	·656	45·4	·676	43·8	·456	87·7	34·3	77·2	37·9	57·3	64·6	25·9	46·2	6	3·77	S.	3	4
March	·832	·489	·653	·754	·389	·579	48·9	·602	47·5	·449	98·1	36·9	85·1	39·1	62·9	63·8	27·0	48·5	7	3·48	N.	4	4
April	·758	·495	·616	·677	·407	·531	53·4	·402	49·0	·262	109·8	46·7	96·7	51·3	76·8	71·5	49·5	61·2	1	0·02	W.	2	4
May	·582	·370	·450	·512	·279	·362	56·4	·365	52·7	·218	115·9	60·1	103·0	63·9	84·6	80·0	52·2	64·9	3	0·57	N.	1	1
June	·635	·199	·427	·552	·160	·350	73·3	·769	74·1	·713	113·6	65·3	101·4	65·1	81·9	80·5	59·0	72·0	21	18·73	N. & E.	7	7
July	·561	·279	·429	·473	·237	·359	75·3	·876	76·3	·845	104·8	69·0	90·2	70·1	79·0	82·1	63·9	72·9	30	34·57	S. W.	8	8
August	·562	319	·440	·489	·270	·370	75·1	·877	76·4	·841	105·4	70·4	89·9	71·8	79·1	81·4	65·0	73·0	27	25·72	N. & W.	8	7
September	·616	·455	·541	·500	·375	·451	71·5	·811	72·7	·730	103·9	61·0	88·0	63·5	77·5	79·0	53·6	69·8	13	7·82	N.	5	5
October	·760	·510	·672	·678	·446	·582	59·1	·593	59·7	·474	100·8	52·1	86·2	55·7	71·8	74·0	48·4	60·2	0	0·00	N.	0	1
November	·888	·739	·818	·791	·671	·727	48·5	·581	49·0	·424	94·8	40·4	82·6	45·0	62·5	66·2	31·6	51·3	0	0·00	S.	0	0
December	·900	·685	·836	·812	·604	·751	42·7	·620	43·6	·425	81·5	32·0	71·4	38·0	56·5	58·1	34·3	47·2	0	0·00	N.	2	2
1875.																							
January	27·937	27·589	27·730	27·850	27·507	27·648	41·4	·670	41·2	·453	77·1	31·9	72·1	35·2	54·1	58·7	32·3	45·9	3	0·62	E.	2	4
February	·863	·558	·747	·781	·515	·683	47·4	·731	47·9	·545	86·0	32·5	75·4	38·5	57·6	63·2	33·2	48·9	7	6·10	W.	5	5
March	·808	·519	·649	·722	·453	·568	52·5	·513	50·1	·329	103·0	44·0	90·1	48·1	70·4	71·2	41·7	55·8	0	0·00	S.	2	3
April	·666	·410	·553	·601	·306	·465	56·2	·414	54·4	·280	109·3	50·7	97·5	60·4	79·7	75·7	46·5	60·7	1	0·01	W.	1	2
May	·662	·403	·533	·588	·318	·448	63·7	·563	62·4	·448	112·0	58·9	100·1	60·8	79·9	76·1	42·4	63·9	12	4·57	S. E.	4	5
June	·545	·255	·375	·419	·188	·292	71·4	·627	71·1	·530	115·0	61·3	100 8	69·0	84·2	81·2	52·1	70·6	10	10·39	N.	4	5
July	·523	·242	·380	·473	·207	·313	75·3	·864	77·3	·778	104·9	69·4	90·2	71·0	80·4	85·0	58·8	73·3	28	22·91	S.	8	8
August	·596	·341	·448	·530	·283	·382	74·7	·891	76·0	·838	101·4	68·8	87·6	69·3	78·4	80·4	64·2	73·1	28	22·90	E.	8	8
September	·668	·378	·555	·589	·302	·468	72·6	·837	73·5	·807	106·3	64·7	88·5	67·2	77·3	83·0	61·0	71·1	22	12·85	N.	5	7

NOTE.—The height of the Barometer Cistern above Mean Sea Level at Karáchí is 2232·41 feet.

Annual Return of work executed in the Drawing Branch of the Computing Office from 1st May 1874 to 1st October 1875.

DESCRIPTION OF WORK.	Number of sheets or diagrams. Finished	In hand	Scale 1 inch =	REMARKS.
Compilation.			Miles.	
Sheets Nos. 1, 2, 3 and 4 Turkestan Map, (3rd edition) with hill shading.	4		32	For Photo-zincography.
Map of Kumaun and Garhwál to illustrate Mr. E. T. Atkinson's Gazetteer of Kumaun and Garhwál, with hill shading.	1		4	ditto. Reduction to ½ scale.
Map to illustrate the report on the Trans-Himalayan Explorations in Great Tibet made during 1872, with hill shading.	1		16	ditto.
Map to illustrate the report on the Explorations Trans-Himalayan and in Nepal made during 1873, with hill shading.	1		16	ditto.
Preliminary Map of Eastern Turkestan to illustrate the reports on Sir Douglas Forsyth's Mission to Kashghar during 1873-74, with hill shading. ...	1		32	ditto. Reduction to ⅓ scale.
Map to illustrate the report on the Pandit's route through Great Tibet from Ladákh to Assam *vid* the Tengri Nur lake and Lhása in 1874. Sheets 1 and 2, with hill shading.		2	16	ditto.
Index Chart to the Degree Sheets of the N. W. Himalaya Series triangulation, with hill shading. ...		1	24	ditto. Reduction to ½ scale.
Map of Afghanistán (by Captain Trotter).		1	16	ditto.
Sheet No. 6 of Levelled Heights.		1	2	ditto.
Do. „ 25 do.		1	2	ditto.
Revised and corrected Map of Routes in Northern India. ...	4		16	ditto. Reduction to ½ scale.
Sketch Map of Tihri Garhwál with adjoining states.	1		8	
Preliminary Numerical Charts.				
Rangír Series Sheet No. 1.	1		4	ditto.
Do. „ No. 2.	1		4	ditto.
Do. „ No. 3.	1		4	ditto.
Assam Valley triangulation, Seasons 1868-69 to 1872-73. ...	1		8	ditto.
Bombay Island triangulation, ...	1		¼	ditto.
Final Charts.				
Great Arc Series.	2		4	ditto. Reduction to ½ scale.
Karáchí Series.	2		4	ditto. ditto.
Gurhágarh Series.	2		4	ditto. ditto.
Ralsún Series.	2		4	ditto. ditto.
Jogí-Tilá Series.	1		4	ditto. ditto.
Sutlej Series.	1		4	ditto. ditto.
N. W. Himalaya Series.	2		4	ditto. ditto.
Degree Charts of the North-West Himalaya triangulation. ...	11	14	4	ditto.
Miscellaneous.				
Examined and reported on 19 fair Maps of Kumaun and Garhwál, Kattywar, Guzerat and Dehra Dún and Siwaliks Surveys.				
Examined 148 proofs of Maps and Charts.				
Colored 7,503 Maps.				
Prepared 24 professional and Office forms on drawing and transfer paper.				For Photo-zincography and Zincography.
Prepared plans of cities of Khotan, Yárkand and Kashghar. ...				
Do. map to show the connection of triangulation of India and Ceylon.				
Corrected Sheet No. 14 of Mussooree and Landour Survey, and inserted numbers of boundary pillars on the several sheets of this survey.				

INDEX CHART
TO THE
GREAT TRIGONOMETRICAL SURVEY
OF
INDIA
BAY OF BENGAL
CEYLON

GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1875-76,

Prepared for submission to the Government of India.

BY

J. B. N. HENNESSEY, ESQ., M.A., F.R.S., &C.,

OFFG., SUPERINTENDENT OF THE SURVEY.

Dehra Dun:

PRINTED AT THE OFFICE OF THE SUPERINTENDENT G. T. SURVEY.

M. J. O'CONNOR.

1877.

THE OPERATIONS OF THE
GREAT TRIGONOMETRICAL SURVEY OF INDIA
IN 1875-76.

List of operations during 1875-76 of the Great Trigonometrical Survey of India showing the pages where they will be found described hereafter in the Report and its Appendix:—

			Report.	Appendix.
		Summary.	2	
No. I.	*Trigonometrical.*	The Madras Coast Series and Ceylon Connecting Triangulation.	5	3—a
„ II.	*Trigonometrical.*	The Operations in the Assam Valley. ...	6	5—a
„ III.	*Trigonometrical.*	The Secondary Triangulation in Burmah. ...	7	8—a
„ IV.	*Trigonometrical.*	The Eastern Frontier Series, Burmah. ...	9	11—a
„ V.	*Trigonometrical.*	The Jodhpur Meridional Series and the Eastern Sind Series.	11	15—a
„ VI.	*Spirit Levelling.*	Operations in Cutch, Kattywar, &c. ...	12	16—a
„ VII. „ VIII.	*Geodetic.*	Electro-telegraphic determinations of Difference of Longitude.	13	20—a 26—a
„ IX.	*Topographical.*	The Surveys in the Dehra Dún District and in the Siwálik Hills.	16	28—a
„ X.	*Topographical.*	The Survey of Kattywar.	18	33—a
„ XI.	*Topographical.*	The Survey of Guzerat.	20	38—a
„ XII.	*Computing Office.*	Calculating and Printing Branches. ...	22	45—a
„ XIII.	*Computing Office.*	Drawing and Photozincographing Branches.	24	55—a

Summary of Operations during 1875-76.

Section.	Probable Errors of Observed Angles.		Geometrical Errors of Triangles.	
	Number	Amount	Number	Amount
I	40	±0″·19	12	0″·63†
I	24	·20	10	2 ·21*
IV	54	·26	18	·34‡
V	27	·15	9	·48§
Averages...	...	±0″·21	...	0″·82

Principal Triangulation has been executed by three field parties, *viz.* Nos. I, IV and V of this report: No. I operated along the southern limit of the Coromandel Coast, District Madura, and on the Ceylon Connecting Series; No. IV in Burmah, Province Martaban; and No. V in Rajputana, Bahâwalpur and Sind. The angles as usual were measured with great theodolites whose azimuthal circles are 24 inches in diameter and are read by 5 Micrometer-microscopes. The average theoretical probable error of an angle and the average geometrical error of a triangle (*i.e.* the difference between the sum of the three observed angles of a triangle and 180° + the spherical excess) are shown in the marginal table here given. The total final out-turn is represented by 48 triangles, which if united would exhibit a chain 217 miles in length and 4182 square miles in area. Similarly the total *preparatory* out-turn executed in advance for 1876-77 is represented by 59 stations and a chain of triangles 270 miles in length. A complete set of astronomical observations was taken for verification of azimuth. In all 71 pillars, platforms, scaffolds and towers, at stations of observation, were constructed; 45 stations were closed and protected; and 54 transferred to the care of District Officers.

Secondary Triangulation has been performed as usual by the field parties Nos. I, IV and V above named, and in particular by No. V which completed a very considerable chain in Rajputana designated the Balmer Series. In addition, Nos. II and III have been employed, exclusively, as during the preceding year, in conducting special series, for the determination of prominent points, respectively in the Assam valley and in Burmah, where known points, on which to base other surveys, are much needed: these special series, it must be understood, are classed as secondary, in the sense that their angles are measured with smaller and more portable instruments, read by verniers, in place of great theodolites; otherwise these chains of triangulation are carried on with every due care and precision. Besides the above mentioned field establishments, the topographical survey parties in Guzerat, Kattywar and Dehra Dún have continued their operations, in closely covering the country about to be delineated with the points of secondary triangulation essential for topographical purposes. The total out-turn of all the field parties is represented by 363 triangles in which the three angles were measured; of these triangles 103 were disposed in series, which if united would exhibit a chain 439 miles in length; besides, over 3000 triangles were established for fixing points. The total area covered by all the preceding triangulation amounts to some 9000 square miles, of which 3500 were closely dotted with points for the topographical surveyor; further, the area included by other triangles to distant hill peaks amounts to nearly 7000 square miles. Of heights, 633 have been determined trigonometrically, and 245 differentially by means of the Aneroid barometer. And as regards pillars, and other forms of construction for stations of observation, 220 such structures have been built.

Topographical Operations have been conducted by field parties Nos. IX, X and XI, respectively, in Dehra Dún including the Siwâlik hills and Jaunsâr Bâwar, Kattywar and Guzerat. The area delineated on scale 4 inches = 1 mile amounts to 1047 square miles, and on scale 2 inches=1 mile to 3629 square miles: in course of these operations about 2900 miles of boundaries and check lines have

† Stations situated on low ground along the sea coast.

* Obtained from the Ceylon Connecting Series, the stations of which were unavoidably placed on small islands but little raised above sea level and much exposed to inclement weather: the observations were thus taken under considerable disadvantages.

‡ The stations of this section with one exception are all situated on hills.

§ On sand hills.

been traversed with the chain, and some 1800 points fixed by the same means, subject to trigonometrical checks, in localities unsuited for triangulation. As regards the province of Guzerat, it having been decided by the Government of India, that in future the scale of survey should be restricted to the 2-inch scale, further delineations on scale 4 inches = 1 mile will be discontinued.

Surveys Completed. The operations under review are so far distinctive in feature, that by their means no less than three separate surveys have been conducted to final and satisfactory completion: *viz.*, the Jodhpur Meridional Series of principal triangles on the meridian of 72½°, running through the Jodhpur, Jesalmer and Bikaner States of Rajputana and Bahâwalpur; the topographical survey of the well known and beautiful valley of Dehra Dún, including its outlying subdivision of Jaunsár Bâwar and the Siwâlik hills; and the Ceylon Connecting Series. By means of the latter, complete unity can now be introduced between the surveys of Ceylon and India, and the required electro-telegraphic measures, in uniting India and Greenwich longitudinally, will now also establish a similar connection for Ceylon.

Spirit Levelling Operations, chiefly in Cutch and Kattywar, Bombay Presidency, have been carried over 421 linear miles, passing through the towns of Rájkot, Muli, Wadhwán, Viramgám, Pátri and Ahmedabad; 166 Bench-Marks were established along the course followed. The results obtained, from the line of levels executed in 1874-75, connecting the three tidal stations of Okhá, Nawanár and Hanstal on the Gulf of Cutch, appear to indicate, that the mean sea level stands progressively higher, as the tidal station is further removed from the open sea up the Gulf.

Calculations and Publications. The subsidary computations of the Sectional Figure South-East Quadrilateral have been completed; also materials for the 6 Synoptical Volumes of this figure have been well advanced: considerable progress has been made in printing all the preceding results, so that a large portion of the pages for 2 Principal and 6 Synoptical Volumes stand passed through the press. The Synoptical Volume which treats of the North-West Himalaya Series has been published, and Principal Volumes III and IV have been bound. A large portion of the North-East Quadrilateral has been reduced by the method of least squares. As regards Cartographical publications, 7 Numerical Charts of Triangulation and 8 of Spirit Levelled Heights, 43 Maps Topographical and 3 of Explorations, besides minor subjects, have been printed and issued: in all 2,475 Charts, 7,931 Maps and 18,000 Professional forms have been supplied.

Miscellaneous. In all 2,725 principal stations situated in 313 districts have been protected and placed under the care of District officers during the past 11 years. Meteorological observations have been taken twice a day throughout the year and the results communicated to the Reporter to Government North-West Provinces. The Records and Library have been maintained in good condition. &c., &c.

Retirements. The department has suffered serious loss by the retirement of its Senior Deputy Superintendent, Colonel T. G. Montgomerie, R.E., F.R.S., and of Mr. W. C. Rossenrode, Deputy Superintendent 3rd Grade; the latter event stands alluded to in art. (19); the omission of the former would leave this report incomplete, notwithstanding that the present opportunity admits only of very brief notice. Lieutenant Montgomerie entered the department in October 1852: soon after he was present at the Base-lines of Chach and Karáchi, in both of which measurements he took a leading share; besides other work, in 1855 he commenced the Topographical survey of the dominions of His Highness the Maharaja of Kashmir, which he finished within the next 9 years. The scale adopted was suitably varied from 2 to 8 miles per inch; the area included some 20 square degrees, or about 77,000 square miles, on which stand the stupendous mountain ranges of Kárákuram, Chángchenmo, Bárálácha, Mustágh, &c.; the chief towns fixed were Jummoo, Srinagar, Leh, Skardo, Hanle, Muzaffrabad, Kishtwár, Bhadrawár, Bárámúla, Drás, Bij Behára, Naushahra, Rajauri, Kargil, &c.; the principal rivers traced were the Indus, Jhelum, Chenab, Zánskar, Sheok, Kishanganga, Astor, Kárákásh, &c.; and of snowy peaks (rising from 16,000 to

the culminating height 28,250 feet of peak at N.E. head of Báltoro Glacier) may be mentioned, Nanga-Parbat, Harámukh, Haramosh, Rákipúshi, Ser Mer, Kárákuram, Bárálácha, &c.: the area of Glaciers extended over more than 1,400 square miles; and the heights ascended, surpassed those recorded as reached by man unaided by balloons.* Lieutenant Montgomerie's name will long continue to be most honorably associated with these operations, which for magnitude, merit and importance are at least unsurpassed.

Returning in 1866 from an absence on furlough for two years, Captain Montgomerie directed the survey of Kumaun and Garhwál with much success. As respects local surveys, those of Mussooree, Kosi Valley and Ránikhet were conducted by him: the last presents an instance of uncommon despatch; it was begun in January 1870 and its 11 maps stood published in the following November. Lastly, he superintended the Trans-Himalayan Explorations, which have contributed so largely to our knowledge of countries that before were almost unknown. It is exceedingly difficult to give an idea of the provinces thus pierced or circumscribed; a brief attempt is however made in the following descriptions of the routes traversed. From Kumaun, northwards to the sources of the Sutlej and Indus, and along a great length of the Brahmaputra eastward through Great Tibet to Lhasa. From Darjeeling, westward to Katmandu, thence over the Dingri Maidan to Shigatze in Great Tibet, onwards in a north-easterly direction round the Tengri Nur Lake, and then southwards to Lhasa. From Kabul *viâ* Bámián and Balkh to Faizabad and Kila Panjah, thence onwards through the Pamirs to Yárkand and Kashghar in Eastern Turkestan, and so back to the Kárákuram pass. From Balkh near the Oxus to Karshi and Bokhara. From Pesháwar to Dír, Chitrál and Zebak in Badakshán. &c., &c. These routes represent a total length of fully 4,500 miles, *along* which, at least, our geographical knowledge has been substantially established.

Lastly, Colonel Montgomerie officiated as Superintendent of Topographical Survey for a while, and as Superintendent of the Great Trigonometrical Survey for 2 years: in addition, his services have repeatedly been honorably mentioned by the Secretary of State and by the Government of India: nor are distinctions at *home* wanting, for he is a Gold Medallist of the Royal Geographical Society as well as a Fellow of the Royal Society. His distinguished services in this Department will long be remembered in connection with his works, and many kind wishes, from those with whom he was here associated, will continue to follow him in his retirement.

Superintendence. The work above summarized and hereafter reported on, was executed under the directions of the Superintendent, Colonel J. T. Walker, R.E., F.R.S., who, proceeding on furlough in April 1876, was succeeded by Captain H. R. Thuillier, R.E., to act in his place. Subsequently on my return from furlough, I was appointed by the Government to relieve Captain Thuillier as Officiating Superintendent: I accordingly received charge on 1st November 1876 and the duty of preparing this report devolved on me.

Explanatory. It only remains to add the following explanatory remark. In compliance with orders received, the Narrative Reports of the Kattywar and Guzerat Survey parties were submitted to Government in original about the first week in last November; this review was commenced soon after, and in due course completed, so far as was practicable in the absence of the Narratives; these were received back on 20th ultimo. Meanwhile, Colonel Walker having resumed charge of the department, my ability to *finish* this report is due entirely to his courtesy.

J. B. N. HENNESSEY.

Deputy Superintendent 1st Grade.

late Officiating Superintendent.

DEHRA DUN:
Dated 1st March 1877.

* As a matter of fact, one of Lieutenant Montgomerie's assistants (Mr. W. H. Johnson) set up his theodolite on the summit of a peak on the Chángchenmo range and measured the required angles; this point is 20,866 feet above sea level.

NO. I.—TRIGONOMETRICAL.

THE MADRAS COAST SERIES AND CEYLON CONNECTING TRIANGULATION.

PERSONNEL.

Major B. R. Branfill, Deputy Superintendent 2nd Grade.
Mr. G. Belcham, Surveyor 4th Grade.
" C. D. Potter, Assistant Surveyor 1st Grade.
Mr. E. W. Laseron, Asst. Surveyor 2nd Grade.
Mr. A. Bryson, Asst. Surveyor 3rd Grade.

(1.) The Rámnád Longitudinal Series, as explained in previous reports, is based on a side of the Great Arc Series; from whence it proceeds along the parallel of 9¼° in an easterly direction, and terminates at the polygon of Uttarakoshamangei, or, more briefly, at the Rámnád polygon, since one of the stations belonging to this hexagon is fixed on a bastion in the fort of Rámnád town. Again, from a southerly side of this figure, the Ceylon Connecting Series with suitable shortened sides continues in an easterly course up to the land's end, the intention being that this chain of triangles should be extended across the Palk Strait, so as to establish on the island of Neduvan suitable stations for the Surveyor General of Ceylon to connect the triangulation of that island with. Up to this stage, the operations were duly reported on in 1873-74.

(2.) During the year 1874-75 Major Branfill proceeded to complete the Ceylon Connecting Series. Also, adopting the northern side of the Rámnád polygon as a base, he finished the first portion of the Madras Coast Series, which, it is intended, shall proceed from Rámnád along the eastern coast and join on to a side of the principal triangulation in the vicinity of Madras. Taking the field early in October, the camp in due course reached Salem: here cholera of a virulent type broke out amongst the men; three deaths occurred, and the District Collector put the establishment in quarantine. On this a panic ensued and a breaking up of the party from desertions became imminent: in brief, Major Branfill had considerable difficulty in reorganizing his camp. Eventually he arrived in safety at Madura, where, dividing his establishment into five working parties, he in the first instance vigorously prosecuted the approximate operations on the Madras Coast Series. Here the country at first was barely passable, being still flooded by the late autumnal rains; however by dint of incessant hard work the required preliminaries for two hexagons were completed in course of two months. Having now arrived at the end of January, Major Branfill commenced the measurement of the principal angles, by himself taking the usual set of circumpolar star observations at the central station of his northern polygon. After this he entrusted the principal observations to Mr. Belcham, who under Major Branfill's care and instruction has proved himself a competent observer with the large theodolite; and deputing two of his assistants to continue the approximate work for next year along the coast, he proceeded to lay out the extension of the Ceylon Series, and finished this work by the end of March. Mr. Belcham followed with the great theodolite and under Major Branfill's supervision completed the required measurement of the principal angles.

(3.) The work thus performed consists of two hexagons on the Madras Coast Series and of a hexagon and a quadrilateral on the Ceylon Connecting Series, forming in all a chain of triangles 80 miles in length and including observations at 21 principal stations. One of the latter gave much anxiety from a singular cause: it was on Rámesweram Island and had been fixed there in 1873-74; the old station however had disappeared, so a new one was established; this had to be watched and protected against the strong wind, which literally blew away some 4 or 5 inches of the surface daily. As regards ray cutting, no less than 348 miles of these lines were cleared, a duty which would have involved far greater time and expense, but for the economical and effective contrivances introduced by Major Branfill for raising the signals as well as the large theodolite to the greatest reliable heights, so as to overlook the lower portion of the foliage with which the country is densely covered. And to provide a sufficient start in the succeeding year, an approximate series of 10 stations was laid out for 36 miles in advance. As already stated, a verificatory azimuth was observed.

ERRATA on this page. *For* 1873-74 *read* 1874-75 and *for* 1874-75 *read* 1875-76.

(4.) Major Branfill's duties were carried on under unusual difficulties. The stations of the Ceylon Series were necessarily all on islands, and visits to these, involving as they did voyages by sea, were not unattended with danger, since this department could not afford to employ better means of transport than those offered by the common open country boats. The series has been laid out with considerable care and skill and the completion of this connecting link between the triangulations of Ceylon and India is a matter for congratulation, not only on the score of its having been well achieved, but in that it meets a long existing desideratum: complete unity can now be introduced between the triangulations of Ceylon and India, and the required electro-telegraphic measures, believed to be not far distant, in connecting India with Greenwich, as respects longitude, will now also establish a similar connection for Ceylon: the ultimate stations fixed by Major Branfill on the island of Neduvan, are those of Amanakkamunai and Urimunai, which afford the required means of junction to the Surveyor General of Ceylon. As respects the operations on the Madras Coast Series, the figures are symmetrical and the work well executed. In concluding this notice it is only just to Major Branfill to add, that his success has been achieved under the unavoidable difficulties presented by the country and climate, and those attending his own failing health.

(5.) Major Branfill having obtained furlough, made over charge of his party on 9th May to Captain W. M. Campbell, R.E, who directed the computations during the recess in addition to his other duties.

NO. II.—TRIGONOMETRICAL.

THE OPERATIONS IN THE ASSAM VALLEY.

(6.) As was stated in the Report for 1874-75, Lieutenant Harman's services were required with the Daphla Field Force for a longer period than he had anticipated when arranging for the prosecution of the Assam Valley triangulation during his absence. Thus on resuming trigonometrical operations in March 1875, he found it impracticable to complete the final observations at all the stations selected, before the setting in of the rains and the consequent termination of the field season. On visiting the remaining stations after the recess, the shoots from tree stumps, bamboos &c. had sprung up to an "astonishing height" on the rays which had been cleared only a few months before, and it became necessary in the first instance to re-open no less than 37 miles of such rays. Proceeding vigorously with the operations, Lieutenant Harman and his assistants succeeded by the end of the season, in advancing the series *finally* from near Sibságar to a little beyond Dibrugarh, or a direct distance of 41 miles. Rays were also cut to the treasury building at Jorhát, so that its position and height were fixed. And as regards Dibrugarh, the church tower at this place was adopted as one of the principal stations of the series. Further, five Revenue Survey pillars were incorporated with the triangulation. And lastly, all the hill peaks north of the Brahmaputra valley, visible from Dibrugarh church tower were fixed.

PERSONNEL.
Lieut. H. J. Harman, R.E., Offg. Assist. Superintendent 2nd Grade.
Mr. W. O'Sullivan, Surveyor 4th Grade.
Mr. E. P. Wrixon, Assist. Surveyor 2nd Grade.
Mr. J. F. McCarthy, Assist. Surveyor 4th Grade.

(7.) From Dibrugarh, the approximate triangulation was continued in two branches. Of these, one proceeds in a south-easterly direction and connecting with Jeypur terminates at the side Deobal Revenue Survey pillar to Hilika Hill station, which is also a station of the Topographical Survey and stands on a spur of the Nágá Hills; the series consists of a chain of 8 triangles. The other and principal branch of the triangulation proceeds north-easterly, spanning the Brahmaputra river up to Sadiya, where it terminates at the side Sadiya Quarter

Guard station to Dikrang Martello Tower station; this series consists of 14 triangles, besides a succession of 3 triangles which are built up like a fan with the Nari Hill as a pivot. This hill being some 600 feet in height, its adoption as a station would carry the series over the difficult waste lands of Paropora both economically and expeditiously. Both these series seem to be well laid out and promise a speedy termination to the operations under Lieutenant Harman's guidance, provided the few long rays do not lead to delay in the final observations.

(8.) The object of adopting the hill Nari as a station is apparent from what has preceded; besides, there is a hill called Pogrosoi, some 15 miles S.W. of the former, which is also highly desirable as a station of observation; because these two hills conjointly present an excellent base for survey purposes if required hereafter, as well as suitable eminences from whence a considerable area of unknown country could be sketched now. Unfortunately both the hills are within Abar territory and therefore may not be visited without the consent of their owners. Being however impressed with the necessity for obtaining access to these hills, Lieutenant Harman, in consultation with the Deputy Commissioner, communicated with the chiefs in question, so that they assembled to meet him with the avowed intention of granting the required permission. The resulting palaver however ended in disappointment, for "each Abar chief" writes Lieutenant Harman "stood forward in turn and forbade the journey: they did not much object to my going alone provided I made no map for the Queen to see," and so on. Subsequent correspondence through Government leaves it probable that the Abar chiefs in question may yet be induced to permit a visit by Lieutenant Harman to the Nari and Pogrosoi hills.

(9.) In all, the angles of thirteen triangles have been finally measured; 35 stations have been selected; 12 post and pillar stations were constructed; and besides other work, 194 miles of rays were cleared under circumstances which make progress in such an operation slow and laborious. Lieutenant Harman's out-turn of work is not only large, but so far as I have the means of judging, it has been well executed. The progress made is very creditable to Lieutenant Harman, who was well supported by two of his assistants, *viz.* Mr. O'Sullivan and Mr. McCarthy.

No. III.—TRIGONOMETRICAL.

THE SECONDARY TRIANGULATION IN BURMAH.

(10.) This secondary triangulation, it will be remembered, was designed with the view of fixing all prominent buildings and other objects in large towns and elsewhere for the purposes of topographical and geological surveys, while lighthouses &c. along the coast were also to be determined in position for the Marine Survey. The required operations were again conducted by Mr. W. G. Beverley aided by the assistants who were under his directions during the previous year and, in addition, by Mr. J. Low, whose services were transferred to the party in order to ensure greater progress and thus to meet the urgent demand which exists for trigonometrical data in Burmah. Mr. Beverley was thus enabled to set three detachments at work in the field, whereby he not only resumed the triangulation begun the season before but extended his operations in other directions as well.

PERSONNEL.

W. G. Beverley, Esq., Offg. Assistant Superintendent 1st Grade.
Mr. J. Low, Surveyor 2nd Grade.
" J. W. Mitchell, Surveyor 4th Grade.
Mr. D. J. Collins, Asst. Surveyor 4th Grade.

(11.) The Series commenced last year was projected to pass southwards through Pegu and Rangoon, but notwithstanding several attempts made, it was found impossible to connect the work with the principal stations of the Eastern Frontier Series, owing to the unfavourable state of the atmosphere which prevailed.

In fact, a sensible portion of the country appears to be under water at the commencement of the field season, and mist and haze greatly delay observations towards the termination of the operations; under these circumstances the surveyor needs to make the most of the interval, and even this is beset with unusual difficulties, as may be gleaned from Mr. Beverley's narrative. Notwithstanding, the required junction above alluded to was effected; further, this series after fixing Pegu and Rangoon was extended to China Bakir: here the old light-house had given place to a new one constructed some 5 miles out at sea; so that it became necessary to open new rays to the new structure, and to this end it was essential to take angles at the old light-house before its demolition. Mr. Beverley performed this duty in person after "wading through a mile of mud and water under a burning sun," and thereby incurred an attack of malarious fever. Approximate operations on the series were subsequently continued along the coast towards Krishna Shoal light, which under favorable circumstances may be reached during next year. The position of China Bakir light-house was supplied, so soon as known, to the Master Attendant.

(12.) Of new series, one was based on the side Myá-yábengkya H. S. to Theyekhír H. S. of the Eastern Frontier principal triangulation, and the selection of stations and other preliminary work carried on up to Tounghoo Pagoda; but this work being commenced late in the season, the haze and rainy weather soon after set in and final observations could not be completed at more than one station. It is intended that the chain of triangles should turn westward on reaching the Boundary north of Tounghoo and, following this limit, should hereafter be connected with another series, also projected in 1875-76, which spans the Irrawaddy river north of Thayetmyo.

(13.) The series last mentioned commences a little north of Thayetmyo; it proceeds along the Irrawaddy and fixing Prome passes on southwards: in a direct distance sixty miles were completed last year of this triangulation, by which moreover numerous points were determined in the civil stations of Thayetmyo and Prome, a large number of heights were obtained and an area of some 3600 square miles covered with trigonometrical points for after purposes of internal surveys: means have also been afforded of making a connection with the line of railway, for the purpose of providing the latter with a reference to sea level. The country passed over is described as densely wooded and well populated.

(14.) The last series projected in 1875-76 remaining to be noticed, is one which Mr. Beverley executed in person, in addition to a general supervision of all the other operations: it commences on the Irrawaddy a few miles north-west of Myanong and proceeding generally in a southerly direction is intended to fix Bassein and to be continued to Cape Negrais. The main ridge of hills in the Henzada district could not be utilized, while the spurs from this ridge were too densely wooded and too short to admit of their being turned to account: eventually Mr. Beverley contrived to find his way between the river and the hills, chiefly by adopting the contrivance of basing his triangles alternately on flank rays all on one flank and cross rays, so that visibility along the other flank, which was impossible, was dispensed with. In a direct distance 81 miles were completed of this triangulation, thus bringing it down to within 32 miles of Bassein.

(15.) Mr. Beverley and his assistants have executed a very satisfactory amount of work and their success is all the more creditable that they have been beset with more than ordinary difficulties.

NO. IV.—TRIGONOMETRICAL.

THE EASTERN FRONTIER SERIES, BURMAH.

PERSONNEL.

W. C. Rossenrode, Esq., Deputy Superintendent 3rd Grade.
Mr. H. Beverley, Surv. 1st Grade.
" J. C. Clancey, Assistant Surveyor 3rd Grade.
Mr. J. O. Hughes, Assistant Surveyor 3rd Grade.

(16.) The principal observations on this series were resumed at the earliest possible date in order that the work should be completed, at least where the long rays occur, before the inevitable hazy weather set in. Accordingly Mr. Rossenrode with the great theodolite took the field on 26th October; the country however was still under water, so that it was impossible to proceed along the land by marching in the usual manner: hence the entire party, with instruments, baggage, and provisions, embarked in boats, and were thus transported from the vicinity of one station to that of another until 8 stations had been completed. Arriving now at Amherst Mr. Rossenrode was able to resume his ordinary mode of locomotion on land, subject however to the usual difficulties which Burmah as yet presents to travellers. He was so far fortunate on this occasion, that the trunk road to Yeh and Tavoy fell within his operations, for though only partially finished it afforded to his party the unusual luxury of travelling along a comparatively made highway. Ordinarily Mr. Rossenrode's marches were made along foot paths cut originally by one of his own detachments in proceeding from a known station towards one as yet unknown; and not only had they no alternative in adopting these forest tracks as roadways, but in the absence of all other lines of communication they had occasionally to march back no inconsiderable distances along gaps of this kind, in order to fall into some other opening which would again conduct them in a forward direction. As to crossing the rivers where they occurred in the interior of the country, the only mode of transport offered was in the form of canoes, which however well suited to the wants of natives of the country (whose wardrobe as described by Mr. Rossenrode consists of a suit or two of palm leaf apparel) "sway, roll, and capsize" but too readily if occupied by men like ours unaccustomed to such boats. Pushing on however with his usual perseverance Mr. Rossenrode eventually found himself at the last station of the season, but only in time to be enveloped by the haze; whereupon he resolutely sat down to wait for rain, which rewarded him with heavy falls, so that the atmosphere having cleared he finished his observations and marched into recess quarters at Moulmein.

(17.) Meanwhile the approximate and secondary operations were vigorously prosecuted by Mr. H. Beverley, assisted by Messrs. Clancey and Hughes. As the pioneer of the whole establishment and enveloped in dense jungle Mr. Beverley frequently cut his way from station to station, compass in hand, followed by his camp equipage. Creeks and tidal streams added as usual to his difficulties, and when at last mounted on the required hill top, he had arrived only at the beginning of a laborious task which involved clearing the site of heavy trees so as to obtain a view around. Proceeding in this manner, he found himself in the vicinity of Yeh, where the strip of British territory is only some 25 miles from sea to Boundary, and the hill of Yetagundine obstructs the view across; under these circumstances he formed a tetragon round the hill, and being thus enabled to continue his progress, he selected an additional double polygon to complete the season's work.

(18.) In respect to general progress made:—principal observations were commenced at the Kathbatong hexagon, about 18 miles north of Moulmein, and were carried down to within some 24 miles north of Yeh, covering a direct distance of 116 miles. The chain thus completed comprises a hexagon, a pentagon, and a heptagon with an internal transverse ray, besides rather more than half of the succeeding figure around Yebudong hill station. In at least two instances Mr. Rossenrode overcame no ordinary difficulties in carrying the great theodolite to the required summit. At Wabiantong the road occupied a detachment a whole

month to fit it for a passage for the instrument; notwithstanding, the ascent proved a perilous undertaking, and when achieved it was found impossible to pitch the observatory tent. A hut supported by poles jammed into fissures between rocks was accordingly adopted as shelter for the theodolite, but the structure was so manifestly insecure that observations were taken only during the day and the instrument packed up every evening. In fact, as Mr. Rossenrode briefly remarks, one face of the hill was so perpendicular that its base could be seen from its summit. It was however at Kamákabo that he overcame almost insuperable difficulties in transporting his great theodolite to the hill summit. The hill was very precipitous with sharp projecting rocks which jutted out in every direction; it was as impossible, with his very limited means, to remove these rocks, as it was to make a road in and out around them: as a last resort, ladders from 16 to 40 feet in length were stretched from rock to rock, and along these ladders he effected a most perilous ascent and descent with no little courage. His great theodolite though one of the lightest of its class weighs 618 lbs, and its smallest case is 300 lbs in weight. "It was a day of rejoicing" says Mr. Rossenrode "when the instrument was brought down in safety". Of further progress; the approximate work of the season supplied a portion of the preceding figures: beginning with Konlah on the island of Belogyún, the selection includes the pentagon and succeeding figure already mentioned, a tetragon, and a double polygon, comprising in all a direct distance of 100 miles: 12 stations in advance remain as a commencement for next season's principal observations. Lastly, by means of secondary triangles, Martaban, Moulmein, Amherst, Double Island light-house, &c. have been amply determined, besides that the prominent peaks along the series have also been fixed.

(19.) Under favorable conditions Mr. Rossenrode's out-turn of work would be considered as a creditable performance; but circumstanced as he was under many disadvantages, he has earned my best commendations. This is Mr. Rossenrode's last contribution to the operations of the Great Trigonometrical Survey of India, for worn out with a long series of arduous and successful achievements he has recently retired from duty, recommended for a special pension in consideration of his good services. Mr. W. C. Rossenrode entered this department in 1839, when it was under the direction of Colonel G. Everest R.A., (afterwards Sir G. Everest, C.B.); subsequently he served under Colonel A. S. Waugh, R.E., (now General Sir Andrew Waugh); and since 1861, under the present Superintendent, Colonel J. T. Walker, R.E: he invariably conducted himself so as to win their confidence and good opinion. He also served with credit on the Budhon, Rangir, Pilibit, and Malunelia series. In 1848 Mr. Rossenrode was selected to lay out the approximate triangulation of the Great Longitudinal, stretching across the desert from Sironj in Central India to Karáchi in Sind; and it was here, under the orders of the late Colonel A. Strange, F.R.S., that he first earned the title he has since so well maintained to rank as one of our most valued pioneers; he lead the way for Colonel Strange's operations in a manner which elicited that officer's highest commendations. Later on, he selected the Karáchi base-line of verification, and continuing to rise in the department he first succeeded to the charge of a field party in 1859. Mr. Rossenrode has since acted as the leader of one of our field establishments for nearly 17 years: during that period he has covered many a district with triangulation and in doing so has travelled many a thousand miles. The greater portion of his services have moreover been rendered in difficult ground, often through dense and uninhabited forests, subject to many dangers, including injury from wild beasts, attacks by predatory tribes, and but too frequently to the deadly and lasting influence of malaria. Through all these, Mr. Rossenrode has worked earnestly and well, and now that the time has arrived when he can toil no more, he leaves the department accompanied by many good wishes that he may long enjoy the reward of his labors in a repose so honorably won.

NO. V.—TRIGONOMETRICAL.

THE JODHPUR MERIDIONAL SERIES AND THE EASTERN SIND SERIES.

PERSONNEL.

Captain M. W. Rogers, R.E., Offg. Deputy Superintendent 3rd Grade.
Mr. W. C. Price, Surveyor 4th Grade.
Mr. C. P. Torrens, Assistant Surveyor 3rd Grade.
Mr. P. F. Prunty, Assistant Surveyor 4th Grade.

(20.) The duties devolving on Captain Rogers were peculiar in the circumstance, that he was required successively to prosecute operations which were separated by 2½° of longitude: in the first instance he was desired to complete the Jodhpur Meridional Series on the meridian of 72½°, and then to begin a new chain of principal triangles, on the meridian of 70°, terminating to the north at the Great Indus Series and to the south at the Karáchi Longitudinal Series. The new triangulation was named the Eastern Sind Series.

(21.) The late and very heavy rains delayed the arrival of stores and men essential for Captain Rogers' field operations; he therefore applied all his available means in starting his assistants, while he proceeded to Deesa, where, at the request of the Government of Bombay and in compliance with the suggestion of the Meteorologist to the Government of India, he inspected the Meteorological Observatory, reported on the same, and laid out a short triangulation in order to connect the observatory and telegraph office with the Karáchi Longitudinal Series. Marching next to the northern terminus of the Jodhpur Meridional Series, he completed the remaining approximate work of the terminal double polygon, and then proceeding with the measurement of the principal angles he finished these operations by the 3rd January.

(22.) Subsequently Captain Rogers marched across to the proposed northern terminus of the Eastern Sind Series with the view of commencing the required triangulation at that end, while Mr. Price was deputed to operate similarly at the southern terminus. Unfortunately the river Indus had washed away several of the old stations about the most convenient locality, so that Captain Rogers was obliged to adopt an initial side west of the given meridian: gradually working on to the required meridian and then turning southwards, he at first had to operate on a country quite flat and covered with dense tree and grass jungle; but pushing onwards through these difficulties, he arrived in a region of sand hills which promises suitably elevated sites and corresponding facilities for the operations next season: his approximate work was closed at the commencement of this hilly region. At the southern terminus Mr. Price was at first unfortunate in being prostrated, with all his men, by fever, so that they resorted to Deesa for medical aid: on recovery from this attack, he made effective progress in advancing the approximate operations northwards. Meanwhile a third detachment under Mr. Torrens began and completed an extensive series of secondary triangles, named the Balmer Minor Series.

(23.) On the Jodhpur Meridional Series, the final angles were measured at 9 principal stations, of which 7 had first to be selected and otherwise prepared for observation: this work completed the terminal double polygon, 21 miles in direct length, which remained to bring the chain of triangles to a conclusion. The series thus begun and finished by Captain Rogers originates at a side of the Karáchi Longitudinal Series, from whence, stretching across the intervening distance of 311 miles, it joins on to the Sutlej Series in the same longitude as it was begun, *i.e.* 72½°: the country included is plentifully dotted with sand hills lying on a waste of sand, but though on the one hand these hills facilitated the operations by presenting elevated sites for stations, on the other, occurring as they do in countries thinly populated and but very scantily supplied with water, Captain Rogers' task on the whole was so arduous that he deserves every commendation for having completed it with success: in the most arid portion of the tract surveyed but three wells of drinkable water were found in a distance of 70 miles.

(24.) On the Eastern Sind Series, the operations were intentionally re-

NOTE.—The *errors* of the Jodhpur Series at its junction with the Sutlej Series are as follows; in Latitude = −0″·17; Longitude = −0″·11; Azimuth = −3″·23; Height = 11 feet; side = − 1·8 inches per mile.

stricted to approximate work: this has been prosecuted vigorously both from north and south; in the former case for 24 miles, comprising 8 stations; in the latter for 110 miles including 24 stations. Although from the primary nature of the work it cannot be exhibited on the chart of final operations which precedes this report, yet it is not to be reckoned the less to the credit of Captain Rogers, who with this excellent start will probably make a very considerable impression next season on the entire series. The secondary triangulation executed on the Balmer Series is 152 miles in length; it fixes 95 points both in geographical position and height, including three important Revenue Survey stations and other prominent and desirable objects.

NO. VI.—SPIRIT LEVELLING.

OPERATIONS IN CUTCH, KATTYWAR, &c.

PERSONNEL.

Captain A. Baird, R.E., Offg. Assistant Superintendent 1st Grade.
Mr. T. H. Rendell, Assistant Surveyor 1st Grade.
Nursing Dass and other Sub-Surveyors.

(25.) During the portion of the recess which remained when submitting his report on the operations of 1874-75, Captain Baird continued to occupy himself with the final reduction of the registrations at each tidal station, and before the resumption of field duties obtained the results which are given in paras. 2 and 3 of his narrative report. He also reduced his spirit levelling operations carried along both sides of the Gulf of Cutch, whereby, it will be remembered, the three tidal stations of Okha, Hanstal, and Nawanár were connected with one another. He was thus in a position to compare the three mean sea levels determined at the tidal stations by means of the differences of height between these stations obtained by spirit levelling; and proceeding in this manner, it will be seen, that reckoning the Bench Mark **A** at Hanstal as *datum*, the following values of mean sea level may be exhibited:—

Values of mean sea level *below* the B. M. **A** at Hanstal tidal station

	feet.
as observed by tidal observations at Hanstal	9·702
as deduced from tidal observations at Nawanár by means of the spirit levelled difference of height	9·895
as deduced from tidal observations at Okha by means of the spirit levelled difference of height	10·273

from which it appears that, provided the spirit levelling is taken as errorless, the mean sea level at Hanstal is higher than that at Nawanár by 0·193 feet, and the mean sea level at Nawanár higher than that at Okha by 0·378 feet. Of these stations it will be remembered that Okha stands furthest out to seaward on the southern margin of the Gulf of Cutch; that Nawanár is about half up the gulf and on the opposite coast; and that Hanstal is at the head of the gulf. It thus seems that the mean sea level stands progressively higher as the station of observation is removed up the gulf. Apart from these facts, the table of tidal results given by Captain Baird shows a close accordance between certain values of mean sea level at the same station; *viz.*, the value obtained from 12½ lunations in comparison with that derived from the 2 lunations which occur from March to May; an agreement which Colonel Walker predicted as very probable.

(26.) On taking the field Captain Baird divided his establishment into two portions, each including two levellers; one of these parties was placed under Mr. Rendell, the other Captain Baird retained under his own charge: both parties were to commence work at bench-marks established the previous season on the line of levels connecting the three tidal stations. Captain Baird commenced with the main line at Jorya, and proceeding south-easterly continued generally in this

course to Rájkot; from here turning north-easterly he passed through Chotila, Muli, &c., and arrived at Wadhwán: from the latter place the line was run along the Bombay Baroda and Central India Railway to Viramgám, and from thence *viâ* Ahmedabad to Mehmadabad; branch lines being projected as usual where required. Mr. Rendell began work with the loop line at Shikárpur and proceeded on to Adisar; beyond this he had to cross that part of the Runn which here divides Cutch from the Pálanpur State and this he was surprised to find under water to a depth varying from 1 to 2 feet: to overcome this difficulty he established suitable stations right across the Runn on pegs driven through the water into the ground; and planting his staves and instruments on these pegs he contrived to get across satisfactorily: he reports the bottom of the Runn here to be concave in the section he made, with a depression of some 2 feet at the centre. Mr. Rendell continued the north-easterly course in which he started to Gokatar, and from thence turning to the south-east he proceeded onwards to Pátri, and eventually closed on the bench-mark at Viramgám established by Captain Baird.

(27.) Captain Baird levelled over 249 miles, and Mr. Rendell over 171 miles, making in all the excellent out-turn of 420 miles, executed in each case by two observers and subject to the rigorous conditions of exactness which in lines of such considerable length are essential: 24 survey stations and 106 *paka* points were connected; besides which 36 bench-marks, embedded in the usual manner, were established. The main line thus executed by Captain Baird and the loop line levelled by Mr. Rendell, when combined with the line between their starting points (Jorya to Shikárpur) established a complete circuit: the difference in height, on comparison at the point common to the two parties at Viramgám, amounted to 0·536 feet, and even assuming that the whole of this error is due to the loop line, which was executed with comparatively inferior instruments, the percentage of error per mile amounts to ·004 feet.

(28.) Unfortunately Captain Baird in course of his duties suffered from fever, so that he obtained 3 months' leave and proceeded to England for a change. Meanwhile however, it had become evident, that the large mass of his tidal observations could not be reduced in this country except at the considerable cost of restricting Captain Baird to the duty of computations solely: as a more expeditious and far more economical measure, Colonel Walker recommended that advantage should be taken of Captain Baird's presence in England, where, in concert with Mr. Roberts of the Nautical Almanac Office, he should be authorized to reduce his observations. This suggestion having met with approval, Captain Baird and Mr. Roberts are now engaged on the work in England.

(29.) Captain Baird made over charge of his party on 12th June to Major C. T. Haig, R.E., who conducted the computations during the recess in addition to his other duties.

NOS. VII AND VIII.—GEODETIC.

ELECTRO-TELEGRAPHIC DETERMINATIONS OF DIFFERENCE OF LONGITUDE.

(30.) These operations it will be remembered were begun in 1872-73 and were then conducted by Captain J. Herschel, R.E., F.R.S., assisted by Captain W. M. Campbell, R.E., who finished the two arcs Madras-Bangalore and Bangalore-Mangalore. Complete discussions by these officers of the instruments employed, the procedure followed and the work executed will be found in the appendix to the report for the year above named, the introduction to these papers by Colonel J. T. Walker, R.E., F.R.S., being placed as usual in the body of the report in

question. In course of the preceding operations it was seen that No. 1 of the pair of transit instruments and B of the two similar chronographs exhibited such serious faults in performance that it became a matter of much importance to detect and eliminate their causes. Meanwhile however Captains Herschel and Campbell proceeded successively on furlough, and on the return of the latter he was deputed to aid Colonel J. F. Tennant, R.E., F.R.S., in observing the Transit of Venus. Thus the longitude observations fell into abeyance for a time, nor were Captain Campbell's services again available for the purpose until the end of April 1875, when it was too late to begin field operations. He therefore turned his attention to the instrumental defects above mentioned, and to such excellent purpose, that he appreciably cured the faults in the transit instrument, and devised remedies for the chronograph which he entrusted to Mr. Doderet, the Mathematical Instrument Maker to Government at Madras, to execute: the details of these matters are given by Captain Campbell in the Appendix to the report for 1874-75.

(31.) During the year under review, Captain Campbell, with the aid of Captain W. J. Heaviside, R.E., undertook the more comprehensive programme of operations hereafter mentioned. He began by applying to the defective chronograph the improvements which had been devised by himself and executed by Mr. Doderet during the recess and found these entirely successful. On this he took the field and proceeded to Hyderabad where he was joined by Captain Heaviside.

(32.) The proposed programme for the season's operations involved the measurements of the following arcs

PERSONNEL.

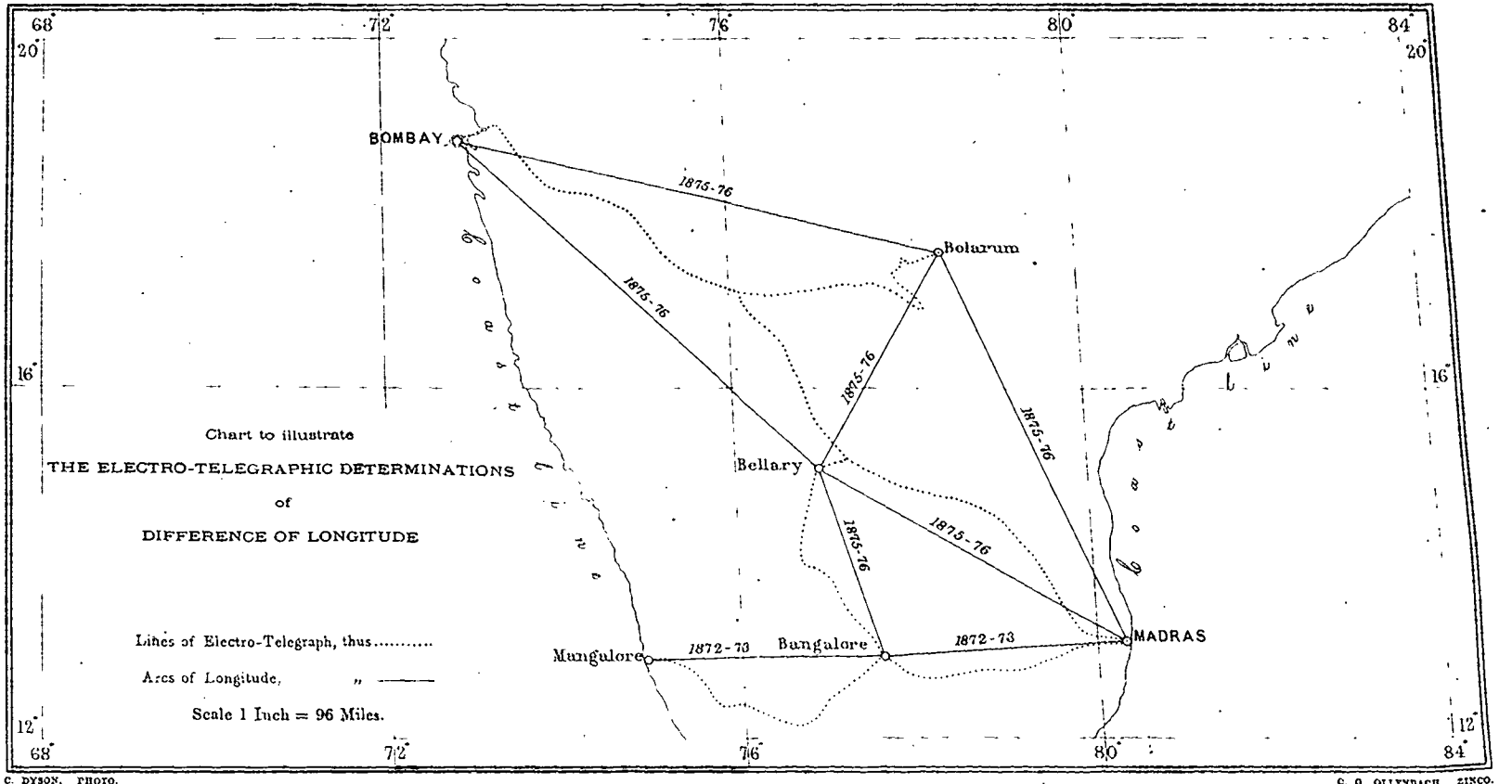
Captain W. M. Campbell, R.E., Offg. Deputy Superintendent 2nd Grade.
Mr. J. Bond, Assistant Surveyor 1st Grade.

Captain W. J. Heaviside, R.E., Deputy Superintendent 3rd Grade.
Mr. H. E. T. Keelan, Surveyor 3rd Grade.

1. Hyderabad-Bombay
2. Bellary-Bombay
3. Bellary-Hyderabad
4. Madras-Hyderabad
5. Madras-Bellary
6. Bangalore-Bellary
7. Bellary-Mangalore.

Of these, 1 to 6 were successfully completed: the arc last named could not be undertaken from want of time. Arrived at Hyderabad, Captain Campbell selected a suitable station at Bolarum in preference to locating himself near the neighbouring telegraph stations at Hyderabad and Secunderabad. Here in due course Captain Heaviside under Captain Campbell's instructions acquired the instrumental and other special knowledge necessary in these operations; after which the observers proceeded to determine values of the personal equation between them, using both transit-instruments for this purpose. Subsequently Captain Heaviside dismantled and removed his instruments to Bombay, Captain Campbell standing fast at Bolarum, and thus the arc Bolarum-Bombay was begun and completed. Next Captain Campbell moved to Bellary, and in conjunction with Captain Heaviside at Bombay measured the arc Bellary-Bombay. After this Captain Campbell proceeded to Bombay, where values of personal equation were determined with Captain Heaviside's transit. Then, the latter officer moving to Bolarum and the former returning to his camp at Bellary, they measured the arc between these stations, thus completing a circuit. The next arc, Madras-Bolarum, was measured with Captain Heaviside at the latter and Captain Campbell at the former station. Subsequently, while his instruments were being shifted to Bellary, Captain Heaviside visited Captain Campbell at Madras, where values of personal equation were determined, this time with Captain Campbell's telescope: after this Captain Heaviside proceeded to Bellary and the observers finished the arc Madras-Bellary, thus completing the second circuit of the season. Finally, while his colleague stood fast at Bellary, Captain Campbell moved to Bangalore and the arc between them was duly measured. The season's operations were closed at Bangalore by determinations of values of personal equations with both the transits.

(33.) Besides the improvements already mentioned, Captain Campbell's experience and skill have enabled him to make other amendments; these will be found described in his narrative, given in the appendix to this report, to which I invite attention. The nicety of appreciation, so essential in these delicate opera-



C. DYSON, PHOTO.

C. G. OLLENDACH, ZINCO.

Photozincographed at the Office of the Superintendent, Great Trigonometrical Survey, Dehra Dún, December 1876.

tions, is apparent in his instrumental arrangements, while his own and Captain Heaviside's skill as observers, combined with their foresight, unremitting care and assiduity, have enabled them to complete an amount of work which is excellent in quality and ample in quantity. The extent of their success is also partly due to the accommodations they enjoyed in respect to the telegraph wires, through the courtesy of Colonel D. G. Robinson, R.E., Director General of Telegraphs, and his officers, whereby, during the measurements of all the arcs, save the first, the observers obtained the use of the line wire uninterruptedly during their programme for each night. In addition, Captain Campbell received every assistance and kindness from Mr. Pogson, Government Astronomer at Madras, while Captain Heaviside enjoyed similar hearty co-operation at the hands of Mr. C. Chambers, F.R.S., Superintendent of the Observatory at Bombay.

(34.) Captain Campbell having completed the necessary calculations during the past recess, has forwarded the following abstract of results, just in time to enable me to include it in this report.

ABSTRACT OF RESULTS.

Circuit I, 1875-76.

ΔL	Bolarum-Bombay,	...	...	...	...	22^m	$48^s \cdot 866 \pm \cdot 0084$
,,	Bellary-Bombay,	...	...	...	...	16	$26 \cdot 941 \pm \cdot 0130$
,,	Bolarum-Bellary,	deduced,	...	...	...	6	$21 \cdot 925 \pm \cdot 0155$
		observed,	...	...	...	6	$21 \cdot 875 \pm \cdot 0126$
		Difference,		...	...		$0 \cdot 050 \pm \cdot 0200$

Circuit II, 1875-76.

ΔL	Madras-Bolarum,	...	...	...	...	6	$54 \cdot 701 \pm \cdot 0123$
,,	Madras-Bellary,	...	...	...	...	13	$16 \cdot 591 \pm \cdot 0124$
,,	Bolarum-Bellary,	deduced,	...	...	...	6	$21 \cdot 890 \pm \cdot 0175$
		observed,	...	...	...	6	$21 \cdot 875 \pm \cdot 0126$
		Difference,		...	...		$0 \cdot 015 \pm \cdot 0216$

Circuits I and II combined, 1875-76.

ΔL		Bolarum-Bombay,	...	...	...	...	22	$48 \cdot 866 \pm \cdot 0084$
,,		Madras-Bolarum,	...	...	...	...	6	$54 \cdot 701 \pm \cdot 0123$
,,	(1)	Madras-Bombay,	...	...	...	...	29	$43 \cdot 567 \pm \cdot 0149$
,,		Bellary-Bombay,	...	...	...	...	16	$26 \cdot 941 \pm \cdot 0130$
,,		Madras-Bellary,	...	...	...	...	13	$16 \cdot 591 \pm \cdot 0124$
,,	(2)	Madras-Bombay,	...	...	...	...	29	$43 \cdot 532 \pm \cdot 0180$
		Difference between (1) & (2),						$0 \cdot 035 \pm \cdot 0234$
		Mean of (1) & (2),				...	29	$43 \cdot 550 \pm \cdot 0117$

Circuit III, 1872-73 and 1875-76.

ΔL Madras-Bellary,	...	...	...	...	13^m	$16^s \cdot 591 \pm \cdot 0124$
„ Bangalore-Bellary,	...	...	...	...	2	$37 \cdot 346 \pm \cdot 0145$
„ Madras-Bangalore deduced,			...	...	10	$39 \cdot 245 \pm \cdot 0191$
Do. measured in 1873,			...	...	10	$39 \cdot 079 \pm \cdot 0102$
		Difference,		...		$*0 \cdot 166 \pm \cdot 0217$

A discussion of the error arising from the method of deducing the collimation and level corrections of the faulty telescope (No. 2) in Season 1872-73 (which will be found with the results of that season) satisfactorily accounts by actual figures for $0^s \cdot 10$ of the large discrepancy $*(0^s \cdot 166)$ found above, while it indicates the probability of a considerably larger quantity. W. M. C.

It will be seen that circuits I and II re-enter very satisfactorily, and that in the alternative circuit formed by combining these two, a partial cancelment of their individual errors occurs. In circuit III, the arc Madras-Bangalore was measured in 1873 before the defects of transit No. 2 had been eliminated; hence the unsatisfactory re-entering discrepancy of $0^s \cdot 166$; this, as Captain Campbell shows, reduces by calculation to $0^s \cdot 066$, with an indicated probability that a further correction is due.

NO. IX.—TOPOGRAPHICAL.

THE SURVEYS IN THE DEHRA DÚN DISTRICT AND IN THE SIWALIK HILLS.

(35.) These surveys, as heretofore, have been carried on conjointly by Captain H. R. Thuillier, R.E., in charge of the Kumaun and Garhwál Party, and by Captain F. Bailey, R.E., Superintendent of Forest Surveys. The latter, working for the requirements of forestry, undertook the internal details of those portions of the country included within the boundaries of the Government forests, leaving the remainder of the ground to be mapped by Captain Thuillier: thus the operations of these officers when combined produce a complete map of the Dehra Dún district, including Jaunsár Báwar, and of the southern portions of the Siwalik Hills so far as the Government forests extend. The allotment of country to each officer will be readily seen by a glance at the index map, in which the portions assigned to Captain Bailey are not colored. Captain Thuillier continued to direct the operations intrusted to him until the end of February, when in compliance with orders he made over charge of his party to Mr. E. C. Ryall and proceeded to join the Superintendent: thus the field duties were conducted successively by Captain Thuillier and Mr. Ryall, and accordingly their separate narrative reports on the subject are given in the Appendix.

PERSONNEL.

Captain H. R. Thuillier, R.E., Offg. Deputy Superintendent 1st Grade.
E. C. Ryall, Esquire, Offg. Assistant Superintendent 2nd Grade.
Mr. C. J. Neuville, Surv. 2nd Grade.
„ W. Todd, „ 2nd „
„ H. Todd, Asst. „ 1st „
„ T. Kinney, „ „ 1st „
„ E. F. Litchfield, Asst. Surveyor 2nd Grade.
Mr. I. S. Pocock, Asst. Surveyor 3rd Grade.
Mr. R. F. Warwick, Asst. Surveyor 4th Grade.
7 Native Surveyors.

(36.) At the close of season 1874-75, the operations remaining in the Dehra valley were restricted to the Eastern Dún, and of this tract the whole had been triangulated while about one half had been traversed. In Jaunsár Báwar the entire country had been triangulated and was so far prepared for plane tabling, subject to such further additions as the subsequent operations might require. Commencing at this stage, Captain Thuillier devided his establishment into two

portions; one of these he placed under Mr. Ryall and sent into Jaunsár Báwar to survey that subdivision, while he retained the other under his immediate directions to operate on the eastern portion of the Dehra Dún. As regards the parts of Kumaun and Garhwál which could not be finished in 1874-75, it may be here stated, that these tracts were not visited: they comprise only some 1,200 square miles, but lying as they do on the north-eastern confines of the district and at considerable altitudes and thus being difficult of access, it was deemed undesirable to incur the necessary heavy outlay which the work would involve, especially in view of finishing the survey in the Dehra Dún district.

(37.) Taking the field about 20th October Captain Thuillier commenced his operations in the Eastern Dún: like the rest of the valley, the country is cut up by numerous watercourses; elsewhere it is generally covered by dense forests, so that the area under cultivation is very small: in addition, the spurs running down from the Himalayas here terminate in abrupt precipices, each succeeded by a forest-covered plateau which is so flat that the water lodges thereon and presents a huge swamp: these swamps range from 1 to 2½ thousand feet above sea level, while the hills north of them rise to over 7,000 feet. Under such circumstances the work was not only difficult but exceedingly tedious and trying to health. Fifty-four miles of check traverses were run to test the work, and Captain Thuillier examined the hill sketching in person, both in the Dehra Dún and also in the Amláwa valley of Jaunsár Báwar.

(38.) Mr. Ryall commenced field work in Jaunsár Báwar on 22nd October. He rightly adopted various watersheds as boundaries for the different plane-tables in place of the co-ordinates which are more convenient on table land, and he established additional trigonometrical points to facilitate the topographical work in the valleys and on the remote patches of country about Sansog and Banpur. The country under survey may be regarded generally as made up of three belts or strips running east and west. The southern belt or up to the parallel of 30° 44′ lies chiefly in Jaunsár; it rises to an average height of some 6,000 feet above sea level, and the Government forests thereon are restricted only to a few detached patches. The middle belt is about 5 miles in width and is covered with rich forests all included in the Government reserves; it lies chiefly in Kándah and comprises several lofty hills as Deoban and Kalanu, rising to an average height above sea level of some 9,300 feet. The northern and remaining belt much resembles the southern strip, both in average height and general features, excepting that the former is much more plentifully covered by Government forests; it lies chiefly in Báwar. The necessity for fixing numerous points on the forest boundaries, imposed on the surveyors considerably greater labour than was anticipated, and this was enhanced by similar requirements in connection with the *khats*, which are internal sub-divisions consisting of 5 to 15 small villages or land-holdings. Along the valleys of the Jumna, the Tons, and the Pábar rivers, the mountains are extremely precipitous.

(39.) In the Dehra Dún, besides the remaining preliminary traverses, 124 square miles were surveyed on the scale of 4 inches to a mile; after which, in order to utilize the services of a few native surveyors who were not sufficiently trained for work on higher ground, the survey of Dehra, including 8 square miles, was completed on the scale of 12 inches to the mile. Besides the foregoing, 38 heights were determined trigonometrically and many others by means of the aneroid barometer. In Jaunsár Báwar, 52 points including 9 heights were fixed trigonometrically, and 430 square miles surveyed topographically on the scale of 2 inches to the mile: further, no less than 1,350 boundary pillars were laid down, and both the cart road and the bridle-road to Chakráta for a distance of 72 miles in all, lying within Jaunsár, were traversed: every endeavour was made to lay down the boundaries of the cantonment of Chakráta, and the required limits were defined so far as the necessary information on the subject could be obtained. With regard to office work, 6 maps have been finally drawn and completed for publication. The work herein reported on completes the survey of the Dehra Dún district, including Jaunsár Báwar, so far as the portions undertaken by this department are concerned; and, as will be seen hereafter, of the

parts assigned to Captain Bailey only 20 square miles in the Dehra valley remain to finish the entire work. As regards the operations under Captain Thuillier and Mr. Ryall now under review, I have carefully inspected the original plane table sheets and can vouch for the general care and accuracy with which they are delineated: they represent an amount of toil and perseverance which can be best appreciated only in presence of the difficult ground operated on, and in view of these conditions, the out-turn of work achieved is satisfactory both as respects magnitude and merit.

(40.) In submitting to Government Captain Bailey's report on his progress during 1875-76, the Officiating Superintendent, Captain Thuillier, makes the following remarks.—"The portions of country surveyed presented very intri-"cate and difficult features throughout, the hills being mostly covered with forest "and jungle, which render a faithful survey more tedious and difficult." Again, "the topography is good, and considering the intricate and rugged nature of the "ground operated on, the out-turn is satisfactory." Further, "Captain Bailey "reports very favorably of the progress made by his Native surveyors and this is "proved by the average monthly out-turn of topographical area by a party con-"sisting of 1 European and 6 Natives having increased from 7¾ square miles "during field season of 1874-75 to 12¾ square miles during the season under "review." Also, "the forest tracts in Jaunsár have been entirely completed, "and with the exception of a small portion of about 20 square miles those in the "Dehra Dún also." Lastly he adds, "having been working conjointly with "Captain Bailey in the general surveys of the Dehra Dún and Jaunsár during the "past three years, I am glad to have this opportunity of testifying to the able and "zealous manner in which he conducts the operations under his charge."

(41.) The successful completion of this survey, undertaken three years ago, reflects much credit on Captain Thuillier, Captain Bailey, Mr. Ryall and the assistants who aided them: by its means we obtain accurate maps with well delineated terrestrial features of a tract of country which is rising daily in importance and value, and which is already rich in extensive tea and other plantations. Moreover the Dehra valley presents considerable areas of land, well watered, in a favorable climate, and otherwise suited for settlements of various kinds; and besides, the country abounds in extensive Government forests the products of which are rapidly increasing in value; but in the absence of the excellent maps now secured, and amid the dense underwood and forest which alternate with open glades and tortuous ravines, it has hitherto been impossible to define a site, in connection with grants of land or for other purposes, even if the site in question could be discovered. These drawbacks now stand removed: the maps are already in local demand and, it may be predicted, will continue to rise in importance.

NO. X.—TOPOGRAPHICAL.

THE SURVEY OF KATTYWAR.

(42.) The topographical survey of this province was conducted as before by Major A. Pullan during the year under review, excepting the period of two months beginning 8th April when he availed himself of privilege leave and Mr. J. McGill officiated in his place: otherwise, the establishment was maintained at its former strength, for while on the one hand Mr. F. Bell obtained furlough for twelve months, on the other, Mr. J. Peyton was appointed instead to do duty with the party. The narrative of the field operations is without event; and notwithstanding that fever and cholera prevailed in Kattywar to some extent, the establishment was fortunate, under judicious management, in suffering only slightly from these causes.

PERSONNEL.

Major A. Pullan, S C., Offg. Deputy Superintendent 3rd Grade.
J. McGill, Esq., Offg. Assistant Supdt. 1st Grade.
Mr. J. Peyton, Surveyor 1st Grade.
" N. C. Gwynne, " 4th "
" W. A. Fielding, Asst. Surveyor 2nd Grade.
Mr. W. Oldham, Asst. Surveyor 3rd Grade.
Mr. G. T. Hall, Asst. Surveyor 3rd Grade.
Mr. H. Corkery, Asst. Surveyor 4th Grade.
Visaji Ragonath Gadboli and 9 other Native Surveyors and Apprentices.

(43.) The country visited lies chiefly in the south-west portion of the province, where two of the southern sheets touch the sea coast; the ground topographically surveyed on the scale of 2 inches to the mile is included in sheets 36, 37, 38, each sheet embracing ½° of longitude and ½° of latitude; and trigonometrical operations were conducted in advance so as to complete sheets 46, 47, and 48 and portions of 40 and 50: besides the foregoing, sheet 10_a, which borders on the Runn of Cutch, was also completed topographically. Thus, the operations under review included the principal towns of Gondal, Jetpur, Junágarh and Jhinjhuwára, of which, Junágarh is reckoned third in importance throughout the province of Kattywar: the country was fertile and well populated, fairly wooded with several kinds of trees, and watered by the rivers Ujat, Uben and Bhádar; the last of these being the largest stream in the province. Nor were prominent terrestrial features wanting, for Girnár mountain lies immediately east of the town of Junágarh, so that the latter stands at the foot of one of the western spurs. This remarkable granite mountain rises to a height of 3,666 feet above mean sea level and is terminated by three sharply defined peaks which are dedicated to deities Hindoo and Mahomedan. The mountain and surrounding country are described by Major Pullan in an interesting account, given in Appendix X.

(44.) Fully availing himself of the favorable conditions prevailing, Major Pullan and his party succeeded in completing an excellent out-turn of work, which, it will be seen below, contrasts very favorably with the amount for the preceding year and is at least equal to the large out-turn for 1873-74. The area topographically surveyed in 1875-76 includes parts of Prânts Hállár, Kattywar, Sorath and Jhalawad:—

	1873-74.	1874-75.	1875-76.	
Topographical ...	2201	1749	2253	square miles.
Trigonometrical ...	2174	2200	1850	„ „
Traverse ...	1235	1117	1600	linear „

Numerical contrasts of such work, as is well known, are in themselves quite insufficient to point to conclusions, failing as they do to impart any idea of the all important local conditions which govern progress in survey operations; but after due consideration of all the existing circumstances and inspection of the original fair drawings, I am of opinion that Major Pullan and his party are due much credit for the success attending their labors during the season 1875-76. In presence of the annual progress hitherto made, it will be seen from the Index chart given in the Appendix, that the survey of Kattywar now begins to approach completion, so that the expectation of finishing the province "within the next five years," expressed by Colonel Walker in his report to Government for 1873-74, is likely to be fully realized.

(45.) As respects fair drawing for publication by photozincography, sheets 31, 42, 43 and 44 have been completed, as usual, on the scale of 2 inches to the mile. Further, suitable delineations have been prepared for the Surveyor General's Office, in order to expedite the engraving and publication of the Atlas sheets for India.

NO. XI.—TOPOGRAPHICAL.

THE SURVEY OF GUZERAT.

(46.) The utilization of the previously executed Revenue Survey maps of certain villages in Guzerat, by combining them with the Topographical Survey of the province now in progress, has presented subjects for considerable deliberation and discussion extending over the years 1872 to 1876. The arguments advanced by the Superintendent, Colonel J. T. Walker, R.E., in support of the views entertained by himself and shared by this department, the procedure of survey adopted and the modifications introduced from time to time as experience showed to be desirable, and the consequent events developed, have all been given year by year in the Administrative reports preceding the one now in hand. The decision which has finally been arrived at, is set forth in the following extracts from letter No. 653 dated 5th August 1876 from the Government of India, in reply to Colonel Walker's letter No. $\frac{32}{328}$ dated 29th March 1876.

PERSONNEL.

Major C. T. Haig, R.E., Offg. Depy. Superintendent 1st Grade.
Lieutenant J. E. Gibbs, R.E., Offg. Assist. Superintendent 2nd Grade.
Mr. A. D'Souza, Surv. 1st Grade.
„ A. D. L. Christie, Surveyor 4th Grade.
Mr. C. H. McA'Fee, Surv. 4th Grade.
„ J. Hickie, Asst. Surv. 2nd „
„ G. D. Cusson, „ „ „
„ S. F. Norman, „ 4th „
„ C. Norman, „ „ „
Messrs. H. G. Ferns, Gopal Vishnu, and 14 other Native Surveyors and Apprentices.

REVENUE SURVEY.

H. D. E. Forbes, Esq., Asst. Supdt.
3 Native Surveyors.

> 2. In reply I am to state that the Governor General in Council agrees to the proposals contained in paragraphs 24—26 in respect to the future conduct of the work in Guzerat *viz.* :—
>
> 1*st* that the plan of giving every detail which the 2-inch scale sanctioned is capable of showing, with a view to the publication of the maps on the same scale, should be adopted for British Districts in Guzerat of which village maps have already been made,
>
> 2*nd* that the plan of giving no more details than can be clearly shown on half that scale, of drawing them boldly, and of exaggerating all the names of towns and villages &c., so as to permit of the maps being readily reduced by photography to the 1-inch scale, and published on that instead of the 2-inch scale should be applied to all other parts of Guzerat,
>
> 3*rd* that two sets of maps of the British Districts should be published; one on the 2-inch scale, including as much as may be required of the contiguous Native States to square the 2-inch maps off conveniently; the other on the 1-inch scale, to juxtapose with the reduced maps of the Native States,
>
> 4*th* that village maps should be utilized in distinguishing between cultivated and barren or forest tracts, in defining village boundaries, and in giving all interior topographical details which stand the test of examination by the topographical surveyors,
>
> 5*th* that the stations of the triangulation and traversing should be placed as frequently as possible at the junction point of three fields, and that the corresponding field numbers should be marked on the maps. The field junction points on the external boundary lines and the internal divisions between cultivated and barren tracts should be taken from the village maps and inserted on the topographical maps, the numbers for every 2nd or 3rd point been given on the map to facilitate identification.

(47.) These orders, restricting the scale of survey to 2 inches per mile, were received too late to be carried out in the *field* operations under notice; but the resulting maps for publication, and all others hereafter prepared, will be *drawn* on the prescribed reduced scale of 2 inches to the mile, as directed.

(48.) The operations of the Guzerat Survey were conducted as heretofore by Major C. T. Haig, R.E., during the twelve months under review, excepting the period of about three months from 13th February 1876, when he availed himself of privilege leave and Lieutenant J. Gibbs, R.E., officiated in charge of the party. Final work was carried on over two separate areas, which may be distinguished as the northern and southern portions of the season's out-turn; and

between these plots, and more particularly north of the latter, a considerable area was prepared by traversing and triangulation for topography in the year following.

(49.) The northern portion topographically surveyed comprises sheets 78 and 79, besides a small area in sheet 10_a, and includes all the Khalsa lands which were visited this year and completed, before Government orders could be made effective, on the usual 4-inch scale. The country was singularly devoid of all through drainage, nor could a single watercourse be found, of sufficient volume to reach the Runn of Cutch on the west or the Sábarmati river on the east: tanks abounded and appeared to offer sufficient receptacles for the total rainfall; besides, there was a large lake called Wanod-na-Saran which presented a surface of some 6½ miles of water when quite full. The principal towns were Viramgám, Mándal, Detroj, Kari, Bechoraji Mátha and Katosan. The Bombay Baroda and Central India Railway traverses the tract in an east and west direction. The country here surveyed includes a large part of Viramgám taluka and a small part of the Sánand taluka of the Ahmedabad collectorate, a portion of Kari Mahal, six villages of Pátan Mahal of the Gaekwar's territory, and a small part of Mahi Kánta.

(50.) The southern portion topographically surveyed comprises sheet 31 and the north-west quarter of 32, and includes the city of Broach, besides the towns of Ankleswar, Sinnar, Tankána, Sukaltirth, Diva, Chandod and Rund Bhúlod, and in addition 24 other towns and villages with populations ranging between one and two thousand souls. The river Nerbudda waters the country, across which the Bombay Baroda and Central India Railway runs for a length of some 25 miles. The tract here surveyed includes parts of Broach, Ámod and Ankleswar talukas of the Broach collectorate; also parts of Sinnar, Mahal (Gaekwar's territory), Rájpipla and Sánkhera Mewas under the Rewákánta Political agency.

(51.) The area traversed and triangulated and thus prepared for the topographical operations of the following year need not be further indicated at present, than by the statement, that it comprises sheets 28, 29 and 30 and lies between the parallels 22° 0′ and 22° 45′ and the meridians 73° 0′ and 73° 30′.

(52.) In all, the area surveyed comprises; of final topography, 924 square miles on the 4-inch and 918 square miles on the 2-inch scale: and of ground traversed and triangulated in advance, 1650 square miles. This represents an excellent out-turn of work, for which Major Haig and his assistants deserve much credit.

(53.) In respect to mapping, the work appears to have been spread unavoidably over a considerable number of sheets, of which several could not be completed though they were well advanced. Seven sections in hand, of degree sheet II, are of this class; but the other half of this sheet was begun and finished, as also was a half section of sheet 80: the printing of names in about 14 sections was completed. Lastly, the compilation of a map of the city of Broach was undertaken, a work which required considerable care and skill, involving as it did transfers from no less than 71 other maps by the Revenue Survey.

(54.) Major Haig describes a method introduced by himself of mounting plane table sections, by which the drawing is readily removed when required and the surface of the paper is not liable to injury.

NO. XII.—THE COMPUTING OFFICE.

CALCULATING AND PRINTING BRANCHES.

(55.) The Computing Office consists in the main of a staff of Native Computers, with whom are associated two selected Surveyors from the Junior branch of the department; these form the Calculating branch, whose varied and comprehensive duties will be found reported on at length in Appendix XII. It is therefore sufficient to mention in this place, generally, that the computing office is required to examine, reduce finally and publish the results of this Survey, as well as to meet the current professional demands which emanate day by day from various sources. These duties obviously involve other professional skill in addition to that of computers; accordingly three *small* auxiliary branch offices for Printing, Drawing and Photozincographing, work in concert with the Calculating branch, and the four branches form what, thus constituted, is called the Computing Office. This office has for years past been supervised by *two* of the survey officers, directed by the Superintendent: the senior of these two (myself) being absent on furlough, the duty of supervision devolved on the remaining officer Mr. W. H. Cole M.A. The latter in turn proceeded on furlough, 21st March 1876, and the Superintendent, Colonel J. T. Walker R.E., also shortly after availed himself of leave to England: under these circumstances, the principal offices, *i.e.*, the Calculating and Printing branches, were placed under the directions of Major J. Herschel R.E., while the Drawing and Photozincographing branches were worked under orders from Captain H. R. Thuillier R.E., who also officiated for the Superintendent. The subdivisions thus temporarily formed, are reported on separately in Appendices XII and XIII. The review here in hand has now reference exclusively to the former Appendix on the Calculating and Printing branches.

Major J. Herschel, R.E., F.R.S., Dy. Supdt. 2nd Grade (in charge from 21st March 1876).
W. H. Cole, Esq. M.A., Offg. Dy. Supdt. 3rd Grade (in charge to 21st March 1876).

Computing Branch.

Mr. C. Wood, Surveyor 3rd Grade.
„ H. W. Peychers, Surveyor 4th Grade.
Baboo Gunga Pershad, Computer.
„ Cally Mohun, Ghose „
„ Kally Coomar Chatterjee, and 11 other Computers.

Printing Branch.

Mr. M. J. O'Connor, Printer.
16 Compositors and 3 Pressmen.

(56.) Major Herschel's report has reference to the thirteen months which ended on 31st October 1876: it primarily exhibits a "Tabular Statement of cost in Rupees of different kinds of Work done" and subsequently adopts for review the classification introduced into this table. The classes thus noticed are treated with so much originality and comprehensiveness as to impart additional interest to his remarks, which will be found at length in Appendix XII. It is therefore sufficient to restrict the review in hand to a general summary of the progress made, and to such brief notices, of a few leading points, as may be entered on without needless reiteration of what is given in detail hereafter. As regards the cost-table above mentioned, it deals with the classification adopted in an effective manner, and in stating the absolute expenditure on each subject, it indicates the directions into which the available working power happens to have been diverted, relatively.

(57.) Reverting for a moment to the Superintendent's administrative report for 1874-75, it was there mentioned that the triangulation of the Sectional Figure known as the South-East Quadrilateral (or S. E. Q.)* had been made consistent by the method of minimum squares, under Mr. Cole's supervision, "in a most satisfactory manner." Subsequently, the remaining computations of Principal work were finished and the printing of these results proceeded with, so that the pages of Volumes VI and VII are approaching completion. And as regards the 6 Synoptical Volumes, *i.e.*, one for each series, of the S. E. Q., considerable

* NOTE.—This figure is bounded on the north by the eastern half of the line from Calcutta to Karáchi; on the east, by the Coast line from Calcutta to Vizagapatam; on the south, by the eastern half of the line from Vizagapatam to Bombay; and on the west, by the Indian middle meridian of 78° (see Index Chart of Triangulation given with this report).

progress has been made, with the records of the Secondary triangulation involved, in correcting, revising and where necessary renewing them, and a sensible impression has been effected on the printing of the results: these volumes it will be remembered, give the facts of the Principal volumes, entitled "Account of the operations &c.," in a condensed form; besides the results of Secondary operations; so as to provide for various local wants, including those of the Geographer and the Surveyor. It may also be suitably mentioned here that Principal Volumes III and IV of the North-West Quadrilateral (or N. W. Q.) have been received back from the Book-binder's hands, and that Synoptical Volume VI, which treats of the triangulation of the Jogí-Tíla and the Sutlej Series in the Punjab, has been bound and published. This latter issue completes the Synoptical publications for the N. W. Q., excepting the volume comprising the chain of triangles which stretches from Dehra Dún to Attock: the series last named, known as the North-West Himalaya Series, includes a great number of Secondary series which are of considerable extent and establish numerous mountain points; thus the work involved, in computing, compiling and printing, as also in drawing and reproducing the several charts required, has been unusually arduous; and hence the time required for publication of this volume is necessarily far greater than for other volumes of its class. Lastly with regard to the volume on the Pendulum operations, a good deal of work was done during the early portion of the year in preparing its pages for the press.

(58.) Among the principal subjects which have occupied the office during the year under review, is that presented by the required reduction of the North East Quadrilateral (or N. E. Q.); this section as originally indicated was bounded as follows: on the south by the eastern half of the line from Calcutta to Karáchi; on the west, by the Indian middle meridian of 78°; on the north, by the British frontier generally; and on the east, by the meridian of Calcutta up northwards to the foot of the Himalayas†: subsequently the section was extended to the east, so as to include four series, *viz.*, the East Calcutta, the Brahmaputra, the Eastern Frontier and the Assam; further, the Budhon Series was excluded in the simultaneous reduction, for in fact the circuit it included was disentangled from the others. The modified section thus undertaken for reduction, by the method of minimum squares, presented several features which differed from those occurring in the Sections N. W. Q. and S. E. Q. already made consistent. In the N. E. Q., the limiting series to the west and nearly the whole of the southern chain had already been determined and fixed by the previous reductions; the circuits were shorter and the triangulation, excepting the eastern extension above mentioned, comparatively inferior in quality; on the other hand, the section in hand presented no less than 49 conditions to be satisfied simultaneously.

(59.) Major Herschel's "Gridiron Function Table", exhibits in a neat and convenient form, the leading facts which convey an idea of the labor and to some extent of the amount of entanglement prevailing in the N. W. Q., the S. E. Q. and the N. E. Q. The labor involved in what is generally the most tedious part of the reduction, is well expressed by "Number of Products forming the same" (*i.e.* Normal Equation Coefficients); the entanglement and other sources of intricacy are not susceptible of accurate numerical expression in a combined form, but a very useful indication in this direction is represented by "Average terms per normal equation"; in all, the table is a valuable contribution to the computer. Quoting Major Herschel's numbers for the three Sectional Figures, in the order N. W. Q., S. E. Q. and N. E. Q., it appears; that the "Number of Circuit triangles" are as 519 : 277 : 573; "Number of Equations of Condition", as 23 : 15 : 49; "Number of Normal Equation Coefficients", as 329 : 165 : 551; "Number of Products forming the same", as 40·0 : 16·7 : 51·0; and the "Average terms per Normal Equation", as 14 : 11 : 11: to these may be added, average number of triangles per circuit, as 162 : 123 : 77. Major Herschel has made good progress in the

† See Index Chart of Triangulation given with this report.

reduction of the N. E. Q. and the results already obtained promise a very successful conclusion to his labors.

(60.) The measures necessary for the protection of our Principal stations have been continued as heretofore, so that the work has now been nearly brought up to date. The transfer of these stations to the care of District Officers was begun in 1865, when, having obtained sanction for the necessary funds, Colonel Walker entered on the difficult and tedious duty in question. In brief, the work involves a certain amount of correspondence with at least one official in every district *all over India* where a station happens to be fixed: approximately there were 350 districts to be dealt with, and 3,000 stations to be parceled out amongst the officers for care and protection of the survey marks imbedded within the structures. These marks present known points on the earth's surface, their latitudes, longitudes and heights being determined, so that in fact, the points stand endowed with properties of considerable value, which however can benefit ourselves or posterity, obviously, only so long as the marks are preserved. Now although, from what has been stated, there are on an average only some 9 points in a district, yet the difficulties of identifying them, necessarily by means of correspondence, are not a few: the stations are fixed from 10 to 60 miles apart, very frequently in desolate or wild regions or on sites not easy of access; in some instances, considerable periods since construction had elapsed, so that local recollections of the events had died out; in others, changes in fiscal boundaries and necessarily in officials added to the difficulties of identification. Thus, descriptive district lists of stations frequently involve tedious correspondence before all the structures can be found by district officers; when this has once been effected, the district is included amongst those designated as "settled". Altogether, 313 districts have been settled, including 2,725 principal stations, leaving some 37 districts and 275 stations to be disposed of. In the work thus completed by the Superintendent, valuable aid has been rendered by Mr. C. Wood who continues to maintain his reputation as an excellent assistant.

(61.) The small auxiliary printing office, which forms part of the professional establishment essential for reduction and publication of the results of this department, has continued to work with efficiency and despatch.

(62.) The out-turn of work, performed successively under Mr. Cole's and Major Herschel's directions, presents ample and satisfactory evidence of successful supervision.

NO. XIII—COMPUTING OFFICE.

DRAWING AND PHOTOZINCOGRAPHING BRANCHES.

(63.) The duty of supervising the Drawing and Photozincographing branches having devolved on Captain H. R. Thuillier, R. E., as explained in para. (55), his report on the work performed by these offices during the twelve months ended 30th September 1876, will be found in Appendix XIII.

DRAWING BRANCH.

(64.) This small auxiliary office has continued to discharge its duties with efficiency, notwithstanding the severe loss it sustained in the early part of 1875, when the two senior and most experienced draftsmen died. The duties in question are briefly as follows. All maps and charts drawn by the Field Establishments undergo examination and, when necessary, correction under the Superintendent's direction; after

PERSONNEL.

Mr. G. W. E. Atkinson, Surveyor 3rd Grade.

3 Draftsmen, 3 Assistant Draftsmen, and 16 Apprentices and Map Colorists.

which they are passed to be photozincographed: other maps and charts which the Field Parties may be unable to prepare are here drawn fair. Besides, various original compilations are undertaken; as, maps of the Northern countries (Turkestan &c.), Exploration routes, charts of spirit levels, &c., &c.: also, the original drawings to illustrate the volumes of the final results are made here, and the press proofs of these and of all maps, charts, &c., are examined and passed: every print requiring coloring is tinted by the apprentices and colorists, and no less than 8502 copies were thus finished in the year under review. In addition, the office now possesses a very useful cartographical collection that needs suitable care in storing; and finally, various miscellaneous drawings are undertaken from time to time, to meet local requirements.

(65.) Of the original publications prepared during the twelve months, the maps of spirit levelled heights occupy the most prominent place in respect to number and labor. These maps are deserving of some special notice. In the original programme, the spirit levelling operations of this Survey were naturally designed for the use of the department alone; it was however soon perceived by the Superintendent, Colonel J. T. Walker, R.E., that the lines of levels might be made subservient to far wider purposes of utility. Now these main lines were necessarily executed with extreme, if not unprecedented, care, precaution and skill, for, owing to the enormous distances which exist between sea boards where alone completely satisfactory checks can be obtained, levelling with the rigour ordinarily sufficient would lead to results of insufficient value. Having established Bench-Marks along various routés, including remote inland tracts where reference to the mean sea level was hitherto unattainable, the resulting facts were printed from year to year for the information of all who were likely to benefit by them and in view of inviting junctions with the B. Ms. in question. Thus in course of time, the Public Works Department and Railway Officers connected their lines with the main lines of the Survey, and it became possible when such junctions had been effected to incorporate all the facts of levelling into a series of suitable maps, provided only that Executive Officers of other departments would contribute tracings of their lines. This condition is however by no means an easy one always to secure; for notwithstanding that the labour of compilation and publication is all undertaken here, and that unless thus preserved, valuable information may certainly be wasted after it has been made to serve its immediate end, yet, the difficulty in obtaining traces, was in a few instances overcome, only by sending a draftsman from this office to do the needful at more or less distant stations. In very many instances however, co-operation was cordially rendered, or the undertaking must have been abandoned. The result is, that up to the present date 26 sheets of spirit levelled heights have been published, and the value of the compilations stands attested by the demand that exists for them.

(66.) I am glad to add that Mr. G. W. E. Atkinson, the chief draftsman, has continued to discharge his duties with zeal and efficiency.

PHOTO-ZINCOGRAPHING BRANCH.

(67.) This small establishment has continued to prove useful and efficient as heretofore. By its means the maps and charts of the Survey are all published under competent direction and within a few months, or even weeks, of completion; the volumes of final results are illustrated with the necessary diagrams, and a large number of professional forms, representing tabulation of mathematical formulæ, are produced with the accuracy so essential in these very necessary aids to calculation.

PERSONNEL.
Mr. C. G. Ollenbach, Zincographer.
„ C. Dyson, Photographer.
2 Apprentices, 1 Mapkeeper and 3 Pressmen.

(68.) The out-turn of work for the twelve months under review may be briefly stated thus.—

Trigonometrical Charts, ...	7	sheets published.
Topographical Maps of Kumaun and Garhwál, Guzerat, Kattywar and Dehra Dún Surveys, ...	43	„
Spirit Level Charts, ...	8	„
Exploration Maps, ...	3	„
Indexes to Surveys, ...	6	„
Gazetteer Maps, ...	2	„
Miscellaneous, ...	2	„
Reprints of Maps already published, ...	22	„
Total,	93	

besides numerous diagrams and forms.

(69.) Contrasting the number of copies printed during the twelve months, under the usual four heads, we obtain the following out-turn of work beginning with 1870-71.

Year	Maps	Charts	Diagrams	Forms
1870-71	6,465	839	13,205	10,482
71-72	10,131	1,375	4,937	13,655
72-73	6,910	2,206	12,055	12,549
73-74	9,207	2,027	3,557	28,125
74-75	7,010	3,015	1,795	24,219
75-76	14,025	1,678	9,722	18,314

Or abstracting from the preceding table, there results as follows,

Subject.	1870-71	1871-72	1872-73	1873-74	1874-75	1875-76
Maps, Charts and Diagrams,	20,509	16,443	21,171	14,791	11,850	25,425
Forms, ...	10,482	13,655	12,549	28,125	24,219	18,314

Further; 7931 Maps and 2475 Charts were issued during the twelve months: the forms printed were all expended, and the diagrams were practically all absorbed in the volumes of final results. These facts speak for themselves and therefore need no commendation. It may be added, that new work keeps pouring in at least as fast as the old work is disposed of, so that a formidable list of subjects to be undertaken, now presents itself for despatch during the ensuing year.

THE LIBRARY.

(70.) In compliance with the orders of Government, No. 3155 of 30th September 1876, that "The state of the Library is to be mentioned in the annual report," I proceed to supply the required information; but as this subject is now noticed for the first time in an Administrative report on this department, it appears desirable to introduce the following brief preliminary statement.

(71.) The total number of printed volumes in the Field office of the Surveyor General and Superintendent Great Trigonometrical Survey amounted in the year 1860 to about 100: this collection was maintained almost exclusively for purposes of computation, so that it consisted chiefly of Numerical Tables; as Logarithms or other auxiliaries to calculation; besides some Mathematical, Astronomical and Geodesical works, and a Star Catalogue; together with occasional copies of travels and other kindred publications. In fact the requirements of the department, with respect to works of reference, were then of a very limited nature: our calculations were restricted to provisional completion of each chain or series of triangles regarded as a separate and detached work: these provisional results were transcribed in triplicate, of which, up to 1857, one copy was forwarded to the Honourable the Court of Directors, another was deposited at Calcutta and the third retained in the Field office. When however numerous chains of triangles had been provisionally completed, and the necessity became urgent, for combining these into consistent masses by the most suitable and rigorous processes due to the excellence of the triangulation, for printing our professional volumes and distributing them so as to secure eligible custodians for the results of this great Survey all over the world, and for illustrating our publications with suitable Maps, Charts and Diagrams, then the demand for works of reference, showing what had been done on other State Surveys, treating of mathematical analysis, or imparting general information, became equally urgent.

(72.) The present small Library, attached to the Computing Office, has thus been gradually formed, chiefly during the last 14 years, to meet this demand. The books are placed in a quadrangular framework* which admits of inspection both from within and without, so that the attacks by White-ants are detected at the outset, and damage from this source is unknown. At the present time, there are in all 2121 volumes in the quadrangular shelf, where they are arranged under 19 heads or classes, so that a class consists of only some 110 volumes on the average. These books constitute what is known as the *Standard* Library; their titles are entered, class by class in a Catalogue, where the date of admission is also registered; and each volume is marked on arrival with the Survey Library stamp, in which the current year is included. Books may not be taken out of the Library room, without first signing a receipt, in which the condition of the volumes taken on loan is stated and a promise made to supply new copies in case of injury to those received. The Standard Library contains only one copy of each work.

A. Mathematics,	F. Philosophical,	L. Manuals,
B. Astronomy,	G. Travels,	N. Photography,
C. { Meteorology, Magnetism,	H. { Geographical, Local,	P. Pamphlets,
D. Geodesy,	I. Historical,	T. Tables,
E. { Geology, Botany, Zoology,	J. Public Records,	U. Almanacs,
	K. Encyclopedia,	V. Catalogues,
		Z. Miscellaneous,

(73.) All duplicate copies are collected together by themselves and classified as above; they constitute what is known as the Duplicate Library and represent to a large extent works kept in stock, for supply to field establishments of this Survey and others, or for consultation and use in the Computing Office; as Numerical Tables, Pamphlets on various subjects, &c. &c..

(74.) All the foregoing are kept in one room, which is 18 feet square. The books are in good order and they are well looked after, but, as is obvious from the dimensions of the room, enlarged accommodation is much needed.

* This quadrangle is necessarily of wood; otherwise it generally resembles the one of iron for Maps in the Ordnance Survey Office, Southampton.

(75.) I cannot conclude this report without suitable allusion to Mr. H. R. Duhan, the Personal Assistant to the Superintendent. Writing as I do of a period when I was absent on furlough, and in this instance of duties, which from their nature are rendered as frequently orally as otherwise, I am constrained to revert to the Superintendent's last report, where acknowledgment is made of Mr. Duhan's "valuable services," and to my personal knowledge of the estimation in which Captain Thuillier (my predecessor as Officiating Superintendent) held the aid rendered to him by the Personal Assistant. Apart from this general testimony and the discharge of his ordinary duties, Mr. Duhan has taken a leading share in preparing the ten years statement of expenses called for by the Secretary of State, a duty which he discharged to the satisfaction of the Surveyor General of India. During my term of office as Officiating Superintendent, I have been much indebted to Mr. Duhan for the prompt and efficient manner in which he afforded me every required assistance. Mr. L. H. Clarke continues to discharge his duties in the corresponding office, and as general store keeper, with care, punctuality and despatch.

(76.) An abstract of the out-turn of work by each of the Survey Parties, whose operations can be exhibited in a tabular form, is given on the following page.

J. B. N. HENNESSEY,

Deputy Superintendent, 1st Grade,

late Officiating Superintendent.

DEHRA DUN;
Dated 1st March 1877.

Abstract of the out-turn of work executed by the Great Trigonometrical Survey Parties, during the Survey year 1875-76.

Description of Details.	I Madras Coast Series and Ceylon Connection. 24-inch Theodolite.	II Assam Valley Triangulation 12-inch Theodolite.	III Burmah Secondary Triangulation. 12-inch Theodolite.	IV Eastern Frontier Series. 24-inch Theodolite.	V Jodhpur Meridional Series. 24-inch Theodolite.	VI Spirit Levelling Operations.	IX Dehra Dún Topographical Survey.	X Kattywar Topographical Survey.	XI Guzerat Topographical Survey.	Total.
Principal Triangulation.										
Number of Stations, newly fixed, ...	17	...	...	14	7	...	...	...	...	38
Do. Triangles, completed, ...	21	...	...	18	9	...	...	...	...	48
Average Triangular error, in seconds, ...	0·63 2·21†	...	...	0·34	0·48	...	...	...	...	...
Do. Probable errors of angles, in seconds, ±	0·19 0·20†	...	...	0·26	0·15	...	...	...	...	...
Astronomical Azimuths of verification, observed,	1	...	...	...	...	...	...	...	...	1
Length of Series, in miles, ...	80	...	...	116	21	...	...	...	...	217
Area of Triangulation, in square miles, ...	518	...	...	3323	311	...	...	...	...	4182
Number of Stations selected in advance, ...	10	...	...	17	32	...	...	...	...	59
Length of Approximate Series, in miles, ...	36	...	...	100	134	...	...	...	..	270
Number of Towers constructed, ...	...	...	...	...	2	...	...	...	...	2
Do. Scaffolds erected, ...	19	...	...	...	...	...	...	...	...	19
Do. Pillars and Platforms constructed,	21	...	...	21	8	...	...	...	...	50
Do. Stations whose elements have been computed,	17	...	...	14	7	...	...	...	...	38
Astronomical Azimuths of verification, computed,	2	...	...	...	...	...	...	...	...	2
Number of Stations finally placed under official protection,	17	...	...	18	19	...	...	...	...	54
Do. of Stations protected and closed, ...	25	...	...	18	2	...	...	...	...	45
Preliminary Charts of Triangulation, ...	1	1	...	1	2	...	...	...	...	5
Secondary Triangulation and Topographical Work.										
Number of Triangles of which all 3 angles have been observed,	...	18	41	2	47	...	...	165	95	363
Number of Triangles of which only 2 angles have been observed, ...	...	...	220	112	140	...	104	1118	324	2018
Number of Stations whose positions only have been fixed, ...	...	...	...	2	...	...	43	*	*	452
Number of Points fixed by intersection, but not visited, ...	8	...	109	58	59	...	27	656	191	1108
Number of Revenue Survey Stations and Boundary junction pillars, fixed by Triangulation, ...	...	...	...	...	3	...	...	...	...	3
Number of Stations and Points whose heights have been determined, ...	5	...	108	6	92	...	47	295	80	633
Length of Secondary Series, in miles, ...	...	41	216	...	152	...	...	...	...	409
Area of Triangulation, in square miles, ...	...	188	3083	...	2642	...	...	1850	1650	9413
Area embraced by Triangulation to hill peaks, in square miles, ...	...	...	4607	2280	...	...	...	...	...	6887
Length of Approximate Series, in miles, ...	...	...	38	...	...	...	...	...	...	38
Number of Pillars, Platforms or Posts constructed or repaired, ...	...	27	23	1	10	...	...	159	...	220
Number of Stations and Points whose elements have been computed, ...	8	15	197	72	...	...	174	*	...	466?
Number of Points fixed by traverse and their elements, computed, ...	...	...	...	...	1	...	1792	*	*	1793?
Length of Boundary lines and Check lines traversed, in linear miles, ...	...	...	...	...	...	...	126	1600	1159	2885
Aneroid Determinations of height,...	...	...	...	...	...	...	245	...	...	245
Area topographically surveyed on scale of 2 inches = 1 mile, in square miles, ...	...	...	...	...	...	...	430	2251	948	3629
Area topographically surveyed on scale of 4 inches = 1 mile, in square miles, ...	...	...	...	...	...	...	124	...	923	1047
Number of Maps, ...	...	...	1	...	...	...	6	12	1‡	20
Levelling Operations.										
Number of miles levelled over, ...	...	...	...	...	...	421	...	...	...	421
Do. of Permanent Bench-Marks fixed, ...	...	...	...	...	...	166	...	...	...	166
Miscellaneous.										
Number of miles of rays cleared, ...	274	250	48	3	104	...	...	...	...	678
Do. do. path-way made, ...	...	...	...	528	28	...	...	...	...	556
Do. Hill tops cleared of forest and jungle,	...	...	35	19	2	...	...	...	...	56

* See appendix. † Ceylon Series. ‡ Besides 7 sections in hand and the printing of 14 maps completed.

APPENDIX.

EXTRACTS FROM THE NARRATIVE REPORTS

OF THE

EXECUTIVE OFFICERS IN CHARGE

OF THE

SURVEY PARTIES AND OPERATIONS.

I. Extract from the Narrative Report—dated 3rd October 1876—of Major B. R. BRANFILL, Deputy Superintendent 2nd Grade, in charge of the Madras Party.

The Party leaves Bangalore for the Field, but is stopped by cholera and brought back.

(2.) The main body of the party to the number of 70, under the Tindal and Daffadar, left recess quarters at Bangalore and marched by the usual route for Madura on the 13th October 1875, but on entering Salem on the 22nd were put in quarantine by the District Collector in consequence of cholera of a virulent type having broken out amongst them, three cases proving fatal. On hearing this I proceeded to join the party at once by train with medical aid, and found them in a state of panic and deserting rapidly. All the newly engaged men refused to go on, demanding their discharge or to be taken back to their homes and families at Bangalore at once. Cholera being very prevalent in the Dindigal and Madura districts ahead, and worse in rear on the route by which they had come, I felt obliged, as they positively refused to remain where they were, to take them by railway to Mysore Territory; and no fresh cases of cholera occurring, they obtained a clean bill of health and were marched into Bangalore under Mr. Bryson on the 2nd November.

Finally takes the Field.

(3.) After recruiting the party in numbers and *morale*, the entire party again left Bangalore for the field, proceeding by rail as far as Madura on the 15th November, and commenced the approximate series operations for the season at Rámnád on the 1st December, having left the 24-inch Theodolite in deposit at Madura, there to remain till actually required for the final observations.

Plan of Operations, Approximate Series.

(4.) I made the following arrangements and disposition of the party for the prosecution of the work. The country to be traversed being low, flat, and much wooded, like that reported on last season (para. 24 of my last annual report for 1874-75), and very few stations and no rays being ready for observations, I threw our whole strength upon the approximate series, and divided the entire party into five pretty equal working parties, one each for my four assistants and myself. Mr. Belcham was to keep to the east flank stations and rays, Mr. Potter to those of the west flank, while Messrs. Laseron and Bryson (the latter in company with myself, being new to this kind of work,) were to prepare the centre of the series.

Actual Progress.

(5.) From the unusually heavy rains of the autumn, the country was at first barely passable, which hindered us much. On the east flank and centre we got on as well as we could expect, but on the west Messrs. Potter and Laseron were greatly delayed on their first rays, although they were between stations which they had themselves selected and built at the close of the last season. I need not however here particularize the share of the work taken by each of us, as it is all shown in detail in the tabular statement attached as usual to this report; suffice it to say that by the end of January, after two months incessant hard work, we had only completed two hexagons; and as it was high time to begin the final observations I sent for the regular carriers to bring the large theodolite, and began the final observations on the 9th February, taking Mr. Bryson with me to record.

The final Observing begun.

(6.) I next proceeded to the centre station Manegandi, and observed the usual azimuth of verification, in which I may remark that I found no inconvenience, want of stability nor any unusual tendency to dislevelment, in the theodolite, from the use of my high (17½ feet triped) stand.

Island Series for Ceylon Connection prepared.

(7.) I now called in Mr. Belcham to take up the final observing with the 24-inch theodolite, leaving Messrs. Potter and Laseron to continue the approximate series in advance for next season, whilst I proceeded to complete the Rámesweram Island Series for the Ceylon Connection; which I found no great difficulty in doing during the month of March.

Final Observations continued by Mr. Belcham.

(8.) Meanwhile Mr. Belcham had observed the final angles at seven of the ten remaining stations of the main series—a good month's work I consider—and now proceeded to observe at the nine stations of the island series, all which he successfully completed on the 25th April, although he was considerably delayed by contrary winds and foul weather: at one station he obtained the first night's observations but could get no more for some days until he had raised the instrument on piles about 8 feet higher, owing to the setting in of an unusually high southerly wind which raised the waves of the intervening sea.

The Rámesworam Sand Hill Station.

(9.) The station on the sand hill near Rámesworam observed to last season could not be found, having been buried deep in the shifting sand, and it was necessary to establish a new one. This station caused me much

anxiety, and I spent much time in watching it during the observations, lest it should be blown away or buried again. It consisted merely of a long 10 feet pile of hard wood driven into the sand at the top of the highest hillock, where there remained just below the surface some of the moisture of last autumn's rains; but as fast as the sun evaporated the moisture, the wind which was uncommonly high for the season, blew away the surface sand daily to the depth of 4 or 5 inches or more; and it was only by continually replacing the sand, and by freely watering and beating it to a smooth and compact mass, that the pile and mark were preserved.

Completion of the Field Season's Work.

(10.) After seeing the completion of the island series, having obtained furlough to England, I left Mr. Belcham to observe the remaining angles of the main series at the three last stations, which he finished by the 4th May, whilst I proceeded to Bangalore to make over charge of the party to Captain W.M. Campbell, R.E.

Outturn of Work necessarily small.

(11.) Briefly stated the season's outturn of work consists of 17 new principal stations, fixed by 21 triangles forming three hexagons and a quadrilateral, extending the series 80 miles (half to the north, and half to the eastward,) besides an astronomical azimuth of verification. Owing to the flat and wooded state of the country the area of the triangulation is exceedingly small: but few secondary points or land marks could be fixed, and but two figures in advance have been prepared for next season, and I much doubt if any greater rate of progress can be expected until the country becomes more favorable for trigonometrical operations.

The Assistants.

The Surveyor, Mr. Belcham, and three Assistant Surveyors attached to the party have all worked hard and well.

Appendix to Major BRANFILL'S Narrative Report by Captain W. M. CAMPBELL, R.E., Officiating Deputy Superintendent 2nd Grade, officiating in charge of the Madras Party, dated 3rd October 1876.

Increased Height of Stations advisable. Height of Theodolite.

(2.) Major Branfill recommended my taking steps during the recess for raising the stations in order to obtain clearer rays, and gave it as his opinion that the best way of doing so would be by increasing the height of the, $17\frac{1}{2}$ feet braced tripod stand for the 24-inch theodolite. This stand was used throughout last season on masonry pillars about 8 feet high, built to support the feet: thus the height of the telescope of the theodolite became $8 + 17\frac{1}{2} + 5$ (about) $= 30\frac{1}{2}$ feet above the ground.

Height of Signal.

(3.) The usual height of the signal platform was about 40 feet, and this Major Branfill seemed to think could not easily be increased. For my own part I felt more inclined to raise the signal if possible, than to alter the tripod stand, considering the slight trouble and expense involved in raising the masonry pillars carrying the latter, if increased height of the observing station should still be necessary. I accordingly had a trial signal platform erected and obtained a height of 58 feet without serious trouble. Mr. Belcham watched the behaviour of this platform by observing the lamp on the top through a theodolite at a convenient distance, and he found that under a strong breeze blowing in gusts the extreme deflection was not above an inch, the platform recovering itself when the wind dropped. This is, I think, highly satisfactory and shows that such a platform may be well trusted for rays averaging 10 miles in length, on which one inch subtends an angle of about 0·33 second.

Difficulty of plumbing.

(4.) Major Branfill also drew my attention to the difficulty of plumbing the lamp at such a height as 40 feet from the ground, except in the calmest weather, without some shelter for the plumb-line. To obviate this I have had cloth funnels constructed to protect the line from top to bottom.

Recess Work.

(5.) As regards the work of the recess—it has been carried on very satisfactorily under the immediate charge of Mr. Belcham, and was completed by the 21st September, on which date the original records and chart were forwarded to Head Quarters.

Apparent Error in trigonometrical Heights.

(6.) There is one point in the reductions which calls for notice, *viz*:—the remarkable and rapidly increasing difference between the sea level and that deduced from the trigonometrical heights of the triangulation running along the coast, with one flank on islands, and latterly entirely on islands, for the purpose of the Ceylon Connection. By spirit levelling connecting the tide-gauge at Tuticorin

with the Cape Comorin Base the error of the trigonometrical heights there was — 7 feet. In the season 1874-75 when the series first struck the coast, 110 miles from the Base-line, the error was found to be — 10·7 feet, increasing to — 12·4 feet in a farther distance of 30 miles. Last season starting with this error of — 12·4 feet we close with — 14·7 feet, after two figures extending 40 miles over sea and islands. The progression is by no means regular, as we have cases of — 18·7 feet and — 17·2 feet between the initial and closing errors of — 12·4 and — 14·7 feet respectively.

Causes surmised.

(7.) These facts tend to show that the refraction affecting grazing rays over the sea is so irregular as to make vertical angles untrustworthy, but I can see no reason why the result should be cumulative, as it certainly appears to be, although I have examined the chart and attempted to find some connection between the growth of the error and the relative positions of the stations as regards their heights, distances apart, and whether the ray passes chiefly over land or sea. The signals obtained were, as might be expected under the circumstances, very bad and wild, having the appearance as Mr. Belcham says of "pillars of fire".

Rough Tidal Observations.

(8.) The references to sea level are of course only approximate, but they were made with some care and cannot be more than a few inches in error. They were obtained by observing the height of the tides on a stake driven into the bed of a sheltered pool, or pit on the beach, just under the station, and measuring the actual height of the station above the mean sea level so arrived at.

(9.) I have to thank Messrs. Belcham, Potter, and Bryson, for their steady application in office.

II. Extract from the Narrative Report—dated 7th August 1876—of Lieutenant H. J. HARMAN, R.E., Assistant Superintendent 2nd Grade, in charge of the Assam Valley Triangulation.

(1.) The preliminary work of the principal series, executed in advance at the close of the field season 1874-75, consisted of 5 rays, 4 post stations, and 2 lines in progress; forming 2 triangles which had not been observed on account of the season being so far advanced, the Dimú station practically inaccessible, and the difficulty of getting at and removing some obstacles from the line Bor Ghop to Melankúr: two rays had been cut from a side of the principal series to fix the treasury building in the civil station of Jorhát. Two rays cut to the Revenue Survey pillar on the south bank of the Dikhu river, near its mouth, were also reported open.

(2.) With a party of men I left Gauháti, by steamer, and arrived at the *ghát* for Jorhát on the 3rd November 1875, starting field work the following day. In re-opening the rays forming the Jorhát triangle one line gave trouble. 2 miles of forest falling in this ray, I found that one edge of the ray required much brushing. I observed the angles of this triangle and then re-opened the triangle to the Revenue Survey pillar of para. 1, and observed the angles: this done I re-opened 4 rays of the past season's work, cut some 5 miles of pathway, repaired three stations, erected three signal platforms, observed angles at one station, and collected stores of rice and *dhán*. Thus was I occupied till the 26th November 1875, when I was joined by Messrs. W. J. O'Sullivan, E. P. Wrixon, and J. F. McCarthy, who arrived from Gauháti, by march, in charge of the main camp.

(3.) Mr. O'Sullivan unfortunately got an attack of fever &c., but was sufficiently recovered and able to start work at the Dimú station by the 14th December. Mr. E. P. Wrixon commenced work at the Dimú station on the 1st December. From that date until the 8th January 1876 he was employed in re-opening 4 miles of the ray Dimú to Tengapania (cut as a final line the previous season) and carrying it on for another two miles towards the latter station, which also he built. On December 12th I assisted him in completing the remaining 1½ miles to the Tengapania station. Mr. McCarthy joined the party at Gauháti on November 4th, marched with the main camp to the field, and began his field work on the 10th of December 1875. Between November 26th and December 10th I re-opened 2 more old rays, repaired one station, observed angles at 2 stations, and cut a trial ray (half of which had been cut the previous season) and gave to Messrs. O'Sullivan and McCarthy the data for cutting the final ray, which they finished by the 23rd December. I have now shown how Messrs. O'Sullivan and McCarthy were employed up to the 23rd December, Mr. Wrixon to the 8th January, and myself to the

13th December. So far nothing worthy of remark occurred, unless it be the heavy cutting on the ray Dimú to Tengapania which had absorbed the labor of a strong party for 2¼ months.

(4.) In re-opening old rays I used to visit the line at points about half a mile apart, ascend a portable ladder, and so direct the cutting of only that growth which showed above the line of grass: it was astonishing the height to which some of the shoots from the tree stumps, bamboos &c., had sprung up in the few months that had elapsed since the lines had been cut through. In most instances I placed the signals on a frame, fastened to the wooden top fitted into an iron telegraph standard and socket, the post being isolated and fixed in position by wire stays. The signals were steady in a fresh breeze, and the height of 30 to 33 feet thus obtained for the signal proved sufficient on all the lines except one, where it was found that the distant heliotrope was obstructed by grass on a high bank, somewhere about the centre of the ray, from the instrument placed at 21 feet above ground. On this line I observed angles to grazing heliotropes and in consequence the triangle produced a large triangle error. The delay thus occasioned would not have occurred, had I provided myself with a 7 or 8 feet portable stand for the theodolite, for it is evident that with an obstruction on the ray nearer the instrument than the distant signal, an increase of 3 or 4 feet given to the height of the instrument stand is much more effective than the same increase of height given to the signal, but I did not think such a stand would be found necessary, as all the grass on the rays of the previous season had then been cut to the ground.

(5.) On the 24th December Mr. O'Sullivan began the ray Tengapania to Dihing, completing it and the building of the Dihing station on the 30th December 1876. He then took up the ray Paonriputra to Burí, finishing it and the building of the Paonriputra station by the 25th February. The tops of the posts of this station were 25 feet above ground, and it was a particularly well built and good station. He was then employed on the preliminary work of the branch series from Dibrugarh to Jaipur. On the 20th April I found it necessary that he should take up the line Rajabeta to Dibrugarh which had been over 2 months in Mr. Wrixon's hands. Mr. O'Sullivan cut an entirely new and successful line in 6 days between the 28th February and May 10th. He had cut on the branch series to Jaipur, one final ray, 8 straight narrow gaps fixing the sites of 6 stations, and had built one post station: he also erected a scaffold 80 feet high so as to obtain the line from the Timolikhat station to the Hilika hill station of the Revenue and Topographical Surveys, in the Naga hills, but bad weather prevented any observations to it. Mr. O'Sullivan closed work on the 10th of May and left for Gauháti with his party by steamer on the 13th May. He was employed at Gauháti on various work until June 1st when he proceeded on three months privilege leave. I have much pleasure in stating that I am well satisfied with the care and labour he bestowed on his work, its style, and the large amount of out-turn.

(6.) On the 8th January Mr. Wrixon took up the ray Tengapania to Sisa completing it on the 29th January: on the 5th February I assisted him in starting work on the line Rajabeta station to Dibrugarh church. The building of the Rajabeta station and the cutting of the two rays from it to the Khalkata and Burí stations, as far as the left bank of the Brahmaputra, were also entrusted to him. On the 20th April Mr. O'Sullivan took over charge of the work on the Rajabeta-Dibrugarh line, and Mr. Wrixon shifted across the river, built the Khalkata station and cleared the few trees standing on the line from it to Dibrugarh church: he then ran the next north flank ray and built the station of Saenga Jan; removed the trees on the lines from it to the Mekla station and Dibrugarh church: he then took up the next flank ray; and on May 12th, finding the line in difficult swamp and cane forest, I closed the work of his detachment for the season. On the 27th May Mr. Wrixon left by steamer for Gauháti, and reached Shillong on the 3rd June.

(7.) On the 23rd December Mr. McCarthy took up the widening of one of my narrow gaps and finished it by December 26th: on the 29th December I assisted him in starting work on the Sisa-Healmara line, which was out of hand on the 14th January. He then built the station at Healmara, ran the next flank ray and built the Burí station, cut two final rays, (data for which I had provided by two trial lines,) ran one more final ray, and cut the line Burí-Rajabeta as far as the right bank of the Brahmaputra: all the above work reported out of hand on the 25th February 1876. Mr. McCarthy completed the line Paonriputra to Khalkata on the 11th March, and then crossed over to Dibrugarh, and opened out as final rays 6 lines forming the right flank of the series, from Dibrugarh up to Pobha Revenue Survey masonry pillar; built one post station, and also all but completed the three rays from the station of Silani, (selected by him on the N. bank of the river,) to three of his stations on the S. bank. Bad weather and the rise of the river compelling him to return to Mekla he finished the building of that station on the 2nd May 1876, remaining there until the 13th of May observing to hill peaks. He then at Dibrugarh observed to the hill peaks until 24th May 1876, and on the 27th he left by steamer for Gauháti and arrived at recess quarters in Shillong on the 3rd June. Mr. McCarthy displayed considerable and unremitting energy in his work. This was his first

season's employment on triangulation, and the successful way he managed it and his large out-turn reflect great credit on him, and I have every reason to be well pleased with his season's work.

(8.) At the close of para. 3 the account of my work is brought up to the 13th December 1875. Till January 1st I was engaged in observing from three stations, on the repair of last year's station of Sisa, and the clearing away of all the trees up to the river bank on 4 lines that converge upon this station. I also ran one trial gap and afterwards widened it into a final ray. During January I cut four trial and 3 final rays, built one post station, and was for 10 days occupied in various work; such as searching for the Khalkata Revenue Survey masonry pillar; traversing to obtain data for the line Lorua to Sisa; raising a mound of earth at the Rajabeta station, and erecting there a ladder 70 feet high; laying out a ray trace as a guide for Mr. Wrixon in determining the line Rajabeta to Dibrugarh church. On 2nd February I left my head quarters at Dihingmuk to help Mr. Wrixon to start work at Rajabeta. Thence I marched to Jaipur, at the foot of the Naga hills, and settled the situation of the stations on the N. flank of the branch series Dibrugarh to Jaipur. This is intended to connect the principal triangulation with the Revenue Survey hill stations, Deohal, near Jaipur, and Hilika, about 7 miles S. of Jaipur, close above the Disang river, on the outer range of Naga hills. This latter station is also common to the Topographical Survey of the Naga hills. I cleared the Deohal hill of jungle and found the marks, both on it and the Hilika hill, intact. From Jaipur I marched across to Sadiya and met the Deputy Commissioner of Dibrugarh, to whom I explained the advantage which the survey would gain, if a certain hill peak on the outer range of the Abar hills, north of the valley, could be occupied as a station. From Sadiya I passed down the river to Dibrugarh and selected the sites of all the stations, except 3, which would form the principal series extending from Dibrugarh to Sadiya.

(9.) On the 25th February I left my head quarter camp for a Miri village at the foot of the Abar hills on the right bank of the Dirjimmu river. The Deputy Commissioner had interested himself in my project for visiting the above mentioned hill peak and I had received good information that several Abar chiefs (who had been informed) were assembled at the above Miri village and had expressed their willingness to conduct me and my men to the hill I had pointed out. But my interview with the Abar assemblage was unsatisfactory, and I had to break up the meeting, as each man in turn stood forward and forbade the journey: they said "the entrance of strangers into their hills was unprecedented"—"they did not much object to my going alone, provided I made no map for the Queen to see, who would in consequence promptly claim them as subjects"—"they could not allow my men to go and cut down their trees on the hill tops and make marks &c." I had no time to spare for a pleasure trip, and I did not go. Work to luminous signals could not well be undertaken if a strong probability existed of the signal parties being molested, hindered, or communication with them in any way obstructed: besides in the densely forest-clad country of the hills and valley north of the river, for speedy work, guides are very necessary. The above circumstances I reported to the Deputy Commissioner and to Head Quarters.

(10.) On March 3rd I went in pursuit of a runaway elephant, a fine tusker attached to Mr. Wrixon's detachment: after 3 days' tracking I came up with him, but could not get him to stand: on the fourth day I left a female elephant and a party of mahouts &c. in the forest, and marched for Dihing station to go on with the observations. During March I closed 5 stations, and was detained in all 7 days in removing from lines obstacles which wholly or partly obscured the distant heliotropes. On April 3rd I heard that the runaway elephant had been enticed into more open ground and that the efforts of the three *kunki* (trained) elephants obtained for the purpose of his capture had proved ineffectual; so I again left my work, chased him about for four days and prevented his getting sleep at night, and on the morning of 8th April, he was secured: he was in capital condition and had been loose in the forests just five weeks.

(11.) After inspecting the work on the Rajabeta-Dibrugarh line, I completed observations at 2 stations by the 13th April. On arrival at my next station Buri I was distressed to find the line Buri to Rajabeta quite wrong, and I had to cut an entirely new line from end to end; this caused me great delay and proved a difficult task. I had only 8 men with me for work; the river had risen high and filled all the side channels of the river, which were dry but a few days previously; added to this, heavy rain set in on the 21st April, mists rose on the river at night, and my observations practically ceased for 7 days: it was the 9th of May when I finally closed the stations of Buri, Rajabeta, and Paonriputra. Between May 10th and 18th I observed angles at 4 new stations of the series, visited the three detachments of the party, and then went down the river to revise the angles at Sisa and Kherkutia stations of the triangle mentioned in paragraph 4 as having a large triangular error. I got clear signals, and the new angles differed from the former values by amounts having the same sign (the new angles were both greater,) proving that the former angles were vitiated by the graze; and the difference being almost equal in amount showed that the obstruction would probably have been found near the middle

of the ray, as I thought it appeared. Having visited Lasua station to observe to hill peaks, without success, on May 18th I caught a downward steamer and reached Gauháti on the 21st May. After arranging the affairs of the party and seeing the building of the elephant shed &c. nearly completed, I left for Shillong on May 24th and arrived there on the 25th.

(12.) The collection and distribution of provisions gave much trouble and labor: nearly all the rice and *dhán* was obtained by private purchase from the villages about Jorhát and Sibságar, on account of the very high prices ruling in the Dibrugarh *bazar* and district. Excepting a few Miri villages, there are no inhabitants in the vicinity of the greater part of series: no local labor was available or procured. In getting parties of signallers &c. passed across the river and side channels of the river many vexatious delays occurred, the men often having to go long distances out of their way to get put across the water. The weather for work on the preliminary series was all that could be desired until April 21st, when very bad weather set in. The general health of the party was excellent.

(13.) Many difficulties were met with in taking the observations: most of the rays were nearly grazing rays; the greater number passed more or less over the river, and the signals at 9 A.M. and 3 A.M. were as a rule very wild. For 3 days in March and 2 in April so thick was the haze and smoke over head that the heliotropes barely showed at all; and on 2 days I got little work on account of a gale from the north west, which blew such dense clouds of sand down the river as to cause the heliotropes to be visible for only short intervals. I had very bad luck with the work to hill peaks, and did not obtain 20 angles before April 20th; afterwards I was more fortunate.

(14.) All the post stations on the south bank of the Brahmaputra except one stood on firm soil, and when the posts of the station and the instrument were properly protected from the wind by screens of grass &c., no difficulty on the score of instability arose; but not so with those stations built on the north side of the Brahmaputra, which were built on sand: the usual grass screens for the wind caused the platform to vibrate, and the tremor was communicated to the instrument. I found it best to be content with only a bit of cloth as shelter for the portable instrument stand. At Paonriputra (a remarkably strong and well built 25 feet post station) it happened that one of the huts for the men was placed about 120 feet distant from the station, and if by chance a man threw down a bundle of firewood at the door of his hut, or chopped a bit of wood, the jog given to the instrument would quite throw off the intersection of the distant signal: one day I measured a distance of 172 feet from the station pillar to where a man was seated fashioning a tent peg on a block of wood, the blows of his *dao* spoiling my angles. At every station on the north bank of the river, if a man came at all quickly up the ladder to the platform a strong tremor was visible in the telescope. To build a station different to the ordinary pattern, on sites of hard sand with a water-logged stratum only a few feet below the surface, did not suggest itself to me as necessary till after the stations had been built and observing had commenced: obviously, better isolation for the posts of the instrument, and comfortable work would have been obtained, if the uprights of the observer's platform had been spread out so that their feet were distant from the three posts, the uprights being supplied with plentiful bracing well nailed, the feet of the uprights not being sunk in the ground but resting on planks, and so forth: this season the only result has been that the observations required painful care. The average triangular error of the principal triangulation is 1·15 seconds.

(15.) The analysis of the heights observed is as follows:—(1.) On 22 rays passing over land and water, comprising 303 observations, the factor of refraction is on every ray negative, the mean value being −·066. (2.) On 2 rays passing almost entirely over the river, and respectively 10½ and 7 miles in length, comprising 36 observations, the factor on each ray is positive, the mean value being +·068. (3.) On 6 rays converging on the lofty stations of Gaorisagar temple (90 feet) and Dibrugarh church tower (50 feet), comprising 84 observations, the factor on each ray is positive, the mean value being +·035.

(16.) The hill peaks observed to extend up to a line bearing from Dibrugarh church 20° east of north.

III. Extract from the Narrative Report—dated 19th July 1876—of W. G. BEVERLEY, Esq., Officiating Assistant Superintendent 2nd Grade, in charge of the Burmah Party.

(2.) It will have been observed from last year's Report, that the triangulation carried on in 1874-75 had not been finally connected with the Eastern Frontier Series. This work was therefore first taken in hand, so as to furnish at an early date the accurate positions of points along the coast for the

Marine Survey. A new light-house about five miles out at sea was also in course of construction, and it was necessary to get some observations from the top of the old light-house before it was dismantled, in order to obtain data for opening a ray to the new light from one of our stations on the coast. The programme of work for the season of 1875-76 was, in addition to the above, the extension of the triangulation along the coast towards the Krishna Shoal light-house, three chains of secondary triangles to start from principal sides of the Eastern Frontier Series, one *viâ* Tonghoo to the Boundary to the north, a second *viâ* Prome and Thâyetmyo to the Boundary, and the third *viâ* Bassein to Cape Negrais to the south.

(3.) I left recess quarters at the end of September to be in time to visit the old light before removal. I visited the place on the 10th of October and obtained the requisite observations, having had to wade through about a mile of mud and water under a burning sun. A touch of malarious fever compelled me to abandon the work at that time; in fact it was impossible to effect any ray clearing with the country entirely under water.

(4.) In order to complete the connection of last year's work with the Eastern Frontier Series, I reconnoitred the country and selected a site for a station which was to be employed in addition to those already selected. I also took observations at three other stations, and obtained data for opening the ray Chanakpho to Chaglibâ. I decided upon using the principal stations of Chaiteo, Chaideo, and Thâlâ, of the Eastern Frontier Series, as the stations of origin.

(5.) After various delays I was enabled to leave Rangoon by the steamer of the 27th of November to take up the triangulation down to Cape Negrais. Before commencing, I went up to Prome to see how Mr. Low had laid out his work. I visited my first station on the 10th of December and closed work on the 15th of April.

(6.) The country traversed by me in the Henzada district was a difficult one for triangulation: it was impossible to get on to the main ridge running parallel to the Irrawaddy, while the spurs from it were not only very densely wooded but were not long enough to admit of both flank stations being selected on them. The country between the river and the foot of the hills is very well populated, but no villages exist up the lateral ravines, and the villagers decline to go beyond a certain distance from their houses from a dread of wild animals and malaria. In most large ravines timber is felled to a considerable extent and there are several cart roads made for conveying the same to points whence they can be floated down: it was not therefore difficult to procure carriage nor except occasionally was any difficulty experienced in obtaining coolies to visit the hills not remote from the villages.

(7.) The country between the river and the foot of the hills is occasionally undulating and covered with patches of dense forest: this added to the difficulties of selecting stations. I succeeded however, by using some stations in the plains on one flank and avoiding intermediate rays, in carrying the triangulation down to within 32 miles of Bassein—a direct distance of 81 miles. The hills here are very low (the forward station being probably below 200 feet) and are a series of plateaus densely wooded. The clearing of such hills in one of the hottest months of the year was likely to occupy three weeks and more, and I considered it advisable to close before the heavy rains came down and rendered the return of elephants to Rangoon a dangerous business. The haze prevented Henzada being fixed this year, the station being over 30 miles in a direct distance from the nearest trig nometrical stations on the hills; but this will be readily done at the commencement of the next field season.

(8). Mr. Low was transferred from Head Quarters and joined the party on the 22nd of October. He was deputed to take up the triangulation from near Prome *viâ* Thâyetmyo to the British Boundary on the north. Owing to the high road to Prome being taken up for the railway, Mr. Low was compelled to have his baggage and establishment brought back from the 40th mile, and to leave Rangoon by steamer for Prome: he commenced work about the end of November.

(9). The principal station of Yongdong near Prome, one of the stations of origin for Mr. Low's triangulation, was found to have the markstones dug out, and a great oblong hole existed instead of the pillar. He was therefore directed to fall back on Kidong station and to use Yongdong, where he put in a mark as an entirely new station.

(10). The country triangulated by Mr. Low lies on both sides of the Irrawaddy river and is densely wooded. Although well populated, it was difficult to get carriage, and it was rendered more difficult by the inadequate assistance afforded him. Mr. Low's reports are a record of delays and difficulties which would have damped the ardour of a less zealous surveyor.

(11). Though new to the country and the language Mr. Low has completed a very satisfactory season's work. He has carried his triangulation up to the Boundary, a direct distance of 60 miles; fixed numerous points in the civil and military stations of Prome and Thâyetmyo; and covered with trigonometrical points an area of about 3640 square miles. Mr Low has also furnished a very large number of heights, and given the means of making a connection between the railway and trigonometrical levelling for comparison or otherwise. The party has been very much strengthened by the additon

of an officer of Mr. Low's ability and zeal. He returned to recess quarters at Moulmein on 3rd of June.

(12.) The triangulation for connecting the work of the previous season with the Eastern Frontier Series was made over to Messrs. Mitchell and Collins, to work simultaneously if possible, one in the Tenasserim district, and the other in the Rangoon division. In order to obtain correct values at an early date, Mr. Mitchell was directed to visit the station of Kalamatong of the Eastern Frontier Series, close to Moulmein, and from it to observe Rangoon and Siriam pagodas, and thereby furnish direct values of these two points to be tested by the values obtained from a series of triangles.

(13.) Mr. Mitchell went up to Kalamatong on the 28th of October and obtained his observations to Rangoon and Siriam after some delay, owing to the station being occupied by Mr. Rossenrode's signalmen, and from the mists rising up from the Gulf of Martaban, over which the rays passed. Mr. Mitchell subsequently visited three other principal stations of the Eastern Frontier Series, and completed his observations on the Tenasserim side by the 17th of December, having been delayed very much by bad signals and unfavorable weather. The distances from these three stations to Máko on the Rangoon side are between 41 and 56 miles, and from Chaiteo to Chaglibá 55·7 miles, and these long sides considerably retarded the work of both Messrs. Mitchell and Collins; the signals shewn being at times very faint, and at other times too unsteady to intersect, due probably to the vapour ascending from the vast expanse of the Gulf of Martaban.

(14.) Mr. Mitchell also visited the four stations of Chaglibá, Chanakpho, Máko, and Dalabán, on the Rangoon side, in order to complete the observations which Mr. Collins was unable from various causes to obtain: he also opened the ray between the first two stations. These four stations were intended for a quadrilateral, but on account of large triangular errors, two triangles were rejected. These errors appear to be due to the rays passing over marshy ground, and over rice fields. These observations were completed by the 7th of February, and Mr. Mitchell proceeded to take up the triangulation *viâ* Tonghoo. The data obtained from these observations enabled me, early in March, to furnish the Master Attendant with the approximate position of the new China Bakír light-house: this position is very near the accurate one since supplied him.

(15.) The haze which had set in when Mr. Mitchell took up the Tonghoo triangulation, prevented his taking any final observations from the starting side which is about 33 miles in length. Having visited one of the terminal stations *viz.* Myayabengkyo, he reconnoitred the ground selected and cleared five hills and laid out the triangulation up to Tonghoo, and returned to take up the observations. He was unable to take final observations from more than one station, *viz.* Toungí; and a few from Tháyekhú the other station of the starting side. The rains had now set in, and he was directed to close and return to recess quarters if he considered there was too much risk in keeping out an establishment exposed to continued rain. The observations should be carried up to Tonghoo by an early date next season, and I have every hope that the triangulation between Tonghoo and Tháyetmyo along the Boundary will be out of hand next season. Mr. Mitchell arrived in recess quarters on the 8th of June having suffered a good deal in health during the field season.

(16.) Mr. Collins took the field on the 28th of October and went to Shántejí station to take an angle there, which could not be obtained last year. The country being here still under water, he proceeded and built Máko station on the top of a high pagoda. He visited Máko, Chaglibá, and Dalabán, in connection with Mr. Mitchell's work mentioned above, and having taken as many angles as he could obtain he returned to take up the triangulation along the coast. As it was necessary to obtain data for opening a ray from Mengálon to the new light-house, he measured a base carefully on the sea coast, as the only means whereby an accurate angle for giving the ray could be obtained. The ground between Mengálon station and the sea coast is low and swampy, and he had great difficulty in opening this ray. Later on he visited the new light out at sea and took observations off the staging between Mengálon station and Elephant Point Column. Mr. Collins reports that the sea was very rough (being the north-east monsoon) and there was a great deal of vibration from the force of the waves striking against the staging. The horizontal angles were very accordant. The side Mengalon to Elephant Point obtained from the base measured on the coast, agrees remarkably well with that deduced from computations brought down by triangulation, and was used in the approximate computation of the latitude and longitude of the new light-house.

(17.) On completion of this work Mr. Collins took up the continuation of the triangulation along the coast from the side Danot to Motyúá. He carried three trial lines between Taolin and Mengálon, a distance of 11 miles, over a tract of country where there was extreme difficulty in procuring potable water which was only obtained in very small quantities and at villages remote from the ray. He took final observations and completed one quadrilateral, opening the intervening rays; and selected the sites of 6 stations for future work. The sites selected appear to be judicious, and under favorable circumstances the triangulation will probably reach Krishna Shoal next year.

(18.) The country along the coast is low and swampy, intersected with numerous tidal creeks, with very few villages and these far apart. It is under water to about the middle of January, and there are no means of moving about except by boats: after each flood tide the ground is submerged to a good distance on each side of the creek, and Mr. Collins had to do most of his marches on foot, wading through slime and wet. The country was the most difficult and trying in Burmah, and Mr. Collins deserves credit for sticking to his work in spite of frequent attacks of illness, although his out-turn of work is small. The experience however that he has gained will be of considerable advantage to him next season. Mr. Collins returned to recess quarters on the 20th of May.

(19.) The men of the Native Establishment have not worked so satisfactorily the last season, the signallers having in repeated instances given a great deal of inconvenience and caused loss of time.

(20.) Tabular statements showing the work done by each officer, accompany this report, and I trust that considering the unfavorable circumstances under which work is obtained at all times in Burmah, the out-turn of work for the past season may be considered satisfactory.

(22.) The Master Attendant at Rangoon, Captain Arnot gave every assistance required to Mr. Collins while employed in fixing the light-house. The work of the Survey always progresses satisfactorily when the District Officers assist the Surveyors. The Deputy Commissioners of Rangoon, Henzada, and Thayetmyo, furnished *parwanas* immediately on application, which were very serviceable, because the Burmans pay every respect to a document bearing the official stamp of the court. The Deputy Commissioner of Prome however refused to give Mr. Low a *parwana* and his refusal was confirmed by the Commissioner of the Rangoon Division. The consequence was serious delay and unnecessary expense entailed on the Government.

IV. Extract from the Narrative Report—dated 18th September 1876—of W. C. ROSSENRODE, Esq., Deputy Superintendent 3rd Grade, in charge of the Eastern Frontier Series.

(2.) The duration of fine observing weather being so short in Burma and the sides of some of the triangles being unavoidably long, owing to the inaccessible mural limestone ranges falling within the triangulation, and it being utterly impossible to make use of any point in them, I had no alternative but to resume field operations earlier this season than I usually did, to endeavour to complete the long sides before the setting in of bad weather.

(3.) Mr. J. O. Hughes was posted to this party by Department Order dated 1st September 1875, and finding that he had had some experience in Assam I determined upon detaching all my three assistants and retaining my Burman writer to record for me in the observatory as he did during the previous field season. Mr. Hughes joined on the 23rd October in a bad state of health caused by an injury he had sustained at Agra, and finding him completely prostrated, I had to alter all my arrangements.

(4.) Mr. Clancey having rejoined from privilege leave on the 23rd October was directed to assist Mr. Beverley in the office.

(5.) I took the field on the 26th October and began final observations at Toungzún H.S. near Moulmein, clouds and rain interrupted my progress. I however completed my observations on the 5th November and returned to Moulmein to rearrange my plans. Mr. Beverley was requested to take up the approximate triangulation on completion of the office work and Mr. Clancey was instructed to fix a principal station on the eastern flank, which was required to complete the figure previously formed. After selecting, building, and preparing the above station, Mr. Clancey was to visit each principal station, and to observe all the high peaks to the east, in the interior, connecting them with one of the principal stations of the series. On completing his observations at each station on the eastern flank, he was to construct a rectangular pillar on it, and make it over for safe custody to the local officials before quitting it: in this way he was to visit seriatim each principal station of the previous season.

(6.) The country being still under water it was utterly impracticable, nay impossible, to march; I therefore engaged boats for the whole party, baggage, instruments, and provisions, and proceeded to Wabiantong H.S., which is 2 miles distant from the Salween river. After the observations were completed the whole party got into the boats and dropped down the river, and encamped at the foot of Mizantong H.S. the same evening. This hill is composed entirely of limestone and the road to it was originally prepared by Mr. Beverley when he selected the station. The tindal was sent to re-cut and improve this road, as the hill was said to be most difficult of access. He and his party were employed a whole month in altering, improving, and making it practicable for conveying the 24-inch Theodolite. With

all his ingenuity and labor the instrument was taken up with difficulty after much toil. I personally superintended its transport, and had the whole establishment to assist: 4 strong new ropes were attached to the box and 6 men holding each rope commenced ascending the hill, dragging up the instrument carriers, thus assisting and supporting them to climb the steep, rugged, and narrow path, step by step. To prevent accidents from breakage of ropes, I followed with a number of men who supported the carriers in the rear, and raised the box when necessary over the obstructing rocks in the passage. The instrument reached the summit in safety, and as the observatory tent could not be pitched, owing to one face of the hill being a perpendicular precipice, the base being seen from the summit, I improvised a temporary one with wood, bamboos, and grass. The station being very much exposed, no reliance could be placed on the supports of the hut which, owing to rocks, could not be driven into them, but rested in fissures, clefts, and indentations found in the rocky surface; I therefore observed duringday light only, taking the precaution of being present all the time the instrument was in position. After sunset the theodolite was boxed, and I retired from the observatory.

(7.) Kamákabo, the most difficult station of the season was next visited: it is the centre of a pentagon and is surrounded by an extensive marsh. The hill is very precipitous, of limestone formation, with its sharp projecting rocks jutting out in every direction. Ladders were used in ascending this station, varying in length from 16 to 40 feet, and by no other means could access be obtained from one rock to the succeeding one above it. I was detained 6 days in altering, strengthening, and constructing these ladders and ramps, which had been previously made by men detached for the purpose. After testing and proving their stability, the 24-inch theodolite was carried up; and it was a day of rejoicing in camp, when the instrument was brought down in safety after the completion of the observations. Many men were wounded by the sharp rocks, notwithstanding all the precautions taken to prevent injury to their feet by pavements of wood over the portions where ladders and ramps were not required.

(8.) Tabutho, Shoisandau, and Konlah, were successively visited, by water. From the latter station I proceeded to Amherst, where the elephants of the party awaited my arrival. The boats were abandoned and I marched to Sindong H.S., and from thence to Kaikamau H.S. The stages to them were made on the Government trunk road which has been constructed from Moulmein to Amherst through a dense forest. Three staging bungalows, 2 rooms in each, have been erected on this road for the convenience of travellers.

(9.) From the 38th mile post another Government trunk road has been surveyed and marked off as far as Yeh, and is eventually to be extended to Tavoy. A portion of this line has been cleared of jungle, and the preliminary work of removing roots, cutting drains on either side, and raising it by throwing up earth, has been done for some miles. It requires bridging and metalling to complete it. In its present state it can be used only during the dry months. For 6 months last season gangs of coolies were engaged and employed under overseers and sub-overseers, but the progress was unsatisfactory: the men from sickness or from other causes either deserted or struck work, and I noticed on my return, after closing operations, that much progress had not been made. From the superabundant population of the Madras Presidency thousands of men who cannot obtain a living there emigrate annually for this Province, where work is plentiful and remunerative. They are very poor and readily take employment at first; but when they have accumulated some money, they bargain for higher wages, and eventually take up contract work, which seems to suit them best, for they can then work or idle as they please.

(10.) This high road partly metalled and partly raised and cleared, and the remainder only cleared of forest, was the only one met with during the season; and with all its imperfections, was of much use to us not only for marching, but for drawing our supplies from Moulmein, which were brought in carts as far as it was metalled and bridged, and from thence by the elephants. The dák-men also used it throughout the season.

(11.) After completing observations at Kaikamau H.S., I proceeded to Thámindo H.S., which was reached in 5 tedious and trying stages: owing to the low marshy state of the country, detours of 2 and 3 miles had to be occasionally made to get over half or one mile of direct distance to avoid swamps, bogs, or other unsafe ground for men and cattle. Two tidal streams had to be crossed. Crossing rivers and streams in the interior of Burmah is something formidable for surveying parties equipped with large and valuable theodolites, tents, and other heavy baggage, which require large and safe boats to ferry them over. At each ferry a small canoe or two are kept for the convenience of travellers, who are mostly pedestrians and generally carry a small box containing a suit or two of clothing made of palm leaves; the indispensable *dah*, a knife with a blade 2 feet long and 2 to 3 inches wide; the umbrella; and a large bag, a receptacle for odds and ends, betelnut box, tobacco, cigars, and cooked rice for use when overtaken by hunger. With the box fastened to his back, his knife in its scabbard hanging from his shoulder by a loop of rope, the bag suspended by tape from the other

shoulder, and with the umbrella in hand, the traveller steps into the canoe and ferries himself over leaving the boat securely fastened on the other side. In the interior of Burmah ferry-men are never found at their posts owing to the uncertainty and small number of travellers; when required they are to be found in the nearest village. At civil and military stations and other important places, where the influx of travellers and trade is great, good boats, and an abundant supply of them are readily obtained, and no delay or inconvenience occurs, the men being always on the spot to collect the toll and demand their fare. In the interior however the difficulty of crossing rivers is great, as canoes are only procurable capable of carrying from 4 to 8 men. A single canoe is at all times unsafe; it sways, rolls, and capsizes if the men do not sit still in it. For crossing over the 24-inch theodolite and the heavy baggage a large number of canoes are required. To collect and lash two and three together to form rafts takes time, and I have been delayed two and even three days in crossing rivers from station to station. In the tidal streams care must be taken to cross them only during high water owing to the quagmire on either bank. Elephants and cattle cannot be landed safely at other times without danger of losing them.

(12.) From Thámindo H.S. I proceeded to Toungboung H.S. from the latter I had to return by the same route to Selúdong H.S. passing near Kaikamau H.S. These circuitous routes cannot be avoided in this province, which is devoid of roads; and to go and return by those prepared for the party becomes necessary, to save time, owing to the great delay and expense of cutting new ones. They have been cut and prepared season after season, and the men have been engaged for a month and more in preparing each road.

(13.) I reached Selúdong H.S. on the 10th day after leaving Toungboung H.S.: the haze was setting in and I was detained there a few days; on completing the observations I proceeded to Thebeyo H.S., which after some days delay from bad weather, was completed, and I hurried on to Yelridong H.S., which I reached on the 4th March: here I remained until the rains set in and cleared the atmosphere and enabled me to complete my observations on the 22nd April. Owing to the thickness of the atmosphere and the daily fires on the Keoktaga and Toungboung rays, these hill stations were completely obscured most of the time I occupied the station of Yebudong.

(14.) The rains having set in I closed work and returned to Moulmein on the 1st May; Messrs. Beverley and Hughes came in a week later, and Mr. Clancey arrived a fortnight after me.

(15.) The approximate operations started with the selection of Konlah H.S., south east of Moulmein, on the island of Belogyún, close on the sea-coast. Selúdong H.S. was next fixed, 50 miles from Moulmein by the road which skirts along the western bone (*sic*) of the range stretching from Moulmein to the Siamese boundary. At first the stations were fixed on both sides of this range, keeping the centre and one of the two terminal stations of the figure on it: where the range formed the boundary between Siam and Tenasserim the most easterly stations were placed on it. The approximate triangulation has been extended from Konlah H.S. to Toungshún H.S., near Nabúley village 20 miles north of Tavoy, by two compound hexagons, a tetragon, and a double polygon. Much difficulty was experienced in the above work, especially near the town of Yeh and to the south of it. On referring to the chart accompanying this report it will be noticed that a tetragon has been introduced on the side Phalein (on the coast) and Sedong (near the Siamese frontier) where the strip of British territory between the coast and frontier is very narrow—25 to 30 miles only. Here the skill and experience of the surveyor was put to the test: wedged in as he was between the sea and frontier, and failing in a quadrilateral owing to the Yetagúndine hill obstructing the diagonal rays, Mr. Beverley who was in charge of the approximate series, extricated himself in a masterly manner by adopting the only feasible figure, a tetragon; thus achieving success and continuing the triangulation. To add to the difficulties of ground, the country between the sides Phalein-Sedong, and Paiapúngún-Nakiadong was almost uninhabited, and in the central and eastern portions entirely so.

(16.) Mr. Beverley was engaged in advancing the approximate triangulation, which he conducted with his usual energy and skill notwithstanding the very difficult nature of the country, which was so densely clothed with jungle that he was obliged to clear his own paths guiding the cutters to the proposed station, his camp following him as he advanced. Creeks and tidal streams enhanced the difficulty of marching and caused considerable delay. Much time was taken up in clearing the densely wooded hill tops for want of coolies, who were collected and brought from long distances. At one station, Deobyú, which is situated 5 stages from the nearest village, it occupied him a considerable time clearing a path to the hill and providing coolies and supplies for clearing, building, and preparing the station. The native official at the large village of Hangan promptly rendered assistance.

(18.) Mr. Beverley has pioneered this party during the whole time I have held charge of it, and to his ability and skill I am greatly indebted for the success attending the operations in this, as well as on the Bider and Biláspur Series.

(19.) Mr. J. C. Clancey, Assistant Surveyor 3rd Grade, left Moulmein on the 4th December 1875, and completed the selection and preparation of Toungboung H.S. for final observations on the 8th January.

The delay was unavoidable owing to desertions of coolies who were brought from great distances, and worked most reluctantly, taking advantage of every opportunity of slipping away. He was for days left with 4 to 6 men to clear tough forest trees of great girth. By my deputing Mr. Clancey to select this station on the eastern flank Mr. Beverley was saved a long march of a fortnight's duration in returning from the station after its completion to begin his work on the western flank.

(20.) After completing Toungboung H.S. Mr. Clancey took up his legitimate duties, visiting all the stations finally completed last season. He observed hill peaks at Thámindo, Shoisandau, Tabutho, and returned the 7-inch theodolite to the depôt at Moulmein from Kamákabo H.S.; being unable from bad health to use it. He constructed all the rectangular pillars and made them over for safe custody to the local officials. He was unable to superintend personally the construction of all the rectangular pillars owing to palpitation of the heart. When climbing hills and marching became painful he proceeded to Shony-Gheen the nearest station and placed himself under the civil-surgeon until he was able to resume work.

(21.) Mr. J. O. Hughes joined this party sick on the 23rd October last and being incapacitated for work obtained leave on medical certificate. On the expiry of his leave on the 1st February, he was directed to assist Mr. Beverley on the approximate triangulation and personally selected three stations and visited the 4th which was fixed by Mr. Beverley. The experience he has gained under Mr. Beverley will be of great use to him in this party, and I have hopes of his being usefully employed the next season on independent work.

(22.) Moung Moung, a Burman lad educated in the Mission and Government Schools at Moulmein, has been now two years with the party as a Burmese and English writer, interpreter, and recorder in the observatory: in the latter capacity he has been of much use for the last two seasons and has done good service.

(23.) The native establishment behaved very well during the field season, but on returning to recess quarters many of the Hindostani carriers took their discharge finding that they could readily obtain service elsewhere. The instrument bearers have also left, but all vacancies have been filled up and the establishment continues efficient. Men of the Madras Presidency are gradually taking the places of the Hindostanis and the establishment will eventually be composed of Madras men.

(24.) The country finally triangulated last season is hilly throughout: long ranges of hills running north and south, with shorter ranges between them, or low spurs jutting out here and there forming connecting links in the chain, extend throughout the triangulated portion in the centre of the Series. Towards the coast the hills are low and isolated and as you retreat further from it, they become more elevated. There are more strips of level ground towards the coast than in the interior. The valley of the Attoran is rather extensive. As the series advances from Moulmein towards Tavoy the population perceptibly diminishes; villages further and further removed from one another are noticed, and towards Solúdong and Thebeye single families having a hut or two occupy the small level spots which they cultivate for a living.

(25.) A large trade in boats is carried on by the people inhabiting the forest. At the base of the hills trees of immense girth are to be found: the tree is selected, felled, and shaped: the digging and scooping process is then performed, leaving the outer surface about three inches thick. The canoes thus roughly made are 20, 40 and 60 feet in length, and from 4 to 6 feet in width in the centre. They are then dragged by two or more elephants over short pieces of timber 3 to 6 inches in diameter placed on the path; these acting as rollers overcome the resistance offered by the uneven ground and the men proceed merrily on, driving the elephants. These sagacious animals are trained to their work and exert themselves to the utmost in dragging the boat to its destination near a navigable stream. The boat is then finished off and sold. The purchaser adds planks to the sides, widening and raising it to the required height. From this capacious dug-out canoe a large boat is formed capable of being taken by sea to Moulmein and Rangoon for sale in the calm winter months. All the village people assist in making the path for dragging the canoe, and each one uses it when his own boat is ready for removal to the stream.

(26.) From information obtained from Mr. Beverley and after consulting the maps of the country in advance, I am of opinion that the series should be continued in a S.S.E. direction from the side Nakiatong to Toungshún, curving it slightly so as to have all the stations on the main land till the termination of the British territory at St. Mathews Island, when as a matter of course some of the numerous islands must be used. For visiting these islands good large sea-going boats will be required for the main and detached parties and must be permanently engaged for the entire field season.

(27.) I believe a base of verification will be required in Tenasserim. If not tied down to a particular locality for the base, I would recommend its being selected at any spot between Mergui and St. Mathews Island wherever suitable ground can be found.

(28.) To Colonel Brown, the late Commissioner of the Tenasserim Division, I am in a great measure indebted for the success which has attended my operations during the entire field season: he

provided me with a *parwána* for myself and for each of my Assistants, bearing his seal and signature, and the document was promptly attended to by all the native local officials throughout his division. He was much interested in the extension of the Survey operations, and impressed on his subordinates that his wishes were to be attended to and his orders carried out, so that the public service might not suffer delay or inconvenience for want of co-operation on their part: the police were also directed to aid and assist whenever their services were needed.

V. Extract from the Narrative Report—dated 21st September 1876—of Captain M. W. ROGERS, R.E., Officiating Deputy Superintendent 3rd Grade, in charge of the Jodhpur Series.

(2.) Owing to the very heavy rains of 1875, the men of the party who were on leave were much delayed in joining, and the medical and other stores of the party for the field season were stopped at Ahmedabad. However, means were found to enable Messrs. Price and Torrens to take the field on the 1st October, and I proceeded to Deesa, where I inspected the Meteorological Observatory, and laid out a small triangulation for connecting it and the Telegraph Office with the Karáchi Longitudinal Series. I then returned to Abú, and having at length received the necessary men and stores, left for the field on the 23rd October. I marched *viâ* Jodhpur and Bikaner to the Baháwalpur territory, and commenced observations at Mansa H.S. on the 4th December. The double figure remaining to complete the series was finished on the 3rd January 1876, at Kaimsir T. S. of the Sutlej Series. Mr. Printy was then sent to close the stations of the season's work and to finish the connection of some Revenue Survey points, whilst the main camp marched, *viâ* Baháwalpur, to the meridian of 70°, on which a new series, called the "Eastern Sind," was to be commenced. This was reached towards the end of the month, and I at once began inspecting the old stations of the Great Indus Series, with a view to fixing on an initial side: unfortunately several of these stations had been completely destroyed by the river, and the series will start from a side considerably west of the meridian.

(3.) The country immediately south of the Indus is quite flat and covered with dense tree and grass jungle, and is inundated for four or five months each year; it therefore became necessary to resort to ray tracing and tower building in the 20 miles which intervene between the river and the sand hills. This style of work was new to all the members of the party, and the progress was in consequence slow. Eight stations were selected, advancing the series 24 miles and reaching the sand hills, on which progress will be more rapid and less expensive. Two towers were built and the materials for two more collected, and 104 miles of rays cleared; leaving but a small distance to be done.

(4.) The party returned to Abú, *viâ* Jesalmer, traversing the desert north of that town, which has hardly ever been visited previously. It differs in no respects from the portions of Bikaner, Jesalmer, and Marwar, visited during the progress of the Jodhpur Series, save in there being fewer villages, owing probably to the comparative absence of the vegetation which supports so many flocks and herds in those states. The country around the city of Jesalmer itself is very rocky, and there are no roads for wheeled vehicles, which are unknown in the city. The party reached Mount Abú on the 26th April, after a long and fatiguing march through the desert.

(5.) This season's work finishes the Jodhpur Series, the longer of the two desert series which remain to complete this part of the principal triangulation of India; and it will not be out of place to give a short *resumé* of the work. It is 311 miles *in length* and was completed in 3 field seasons and one month, from the first reconnoissance for stations to the last final observed angle: it covers an area of 8,041 square miles, besides 4,318 sq. miles of secondary triangulation and, with the exception of a small portion south of the river Luni, passes over a sandy country of nearly utter desolation. The country is covered with sand hills of every form, in all directions, dotted here and there with tufts of coarse grass and stunted shrubs. The villages, few and far between, are collections of squalid wigwams, situated near spots where wells, sometimes 200 feet in depth, have been excavated with great labor, to be rewarded often with only brackish water. In the whole distance from the Luni to the Sutlej Series, 250 miles, the series met with only one place—Phalaudi—which could be dignified by the name of a town, and four which ranked as decent villages. All is barren and desolate, but perhaps the southern portion of Baháwalpur carries off the palm in this respect. There the series passed over a distance of 70 miles, in which there were only three wells of drinkable water, and these were collected within a space of 10 miles.

(6.) In no native state in which I have worked, has such hearty and effective assistance been rendered to me, as by the Political Superintendent of this country. Whilst alluding to this, I also thankfully acknowledge the assistance and kindness which we experienced from the Rulers and Political Agents of Marwar, Bikaner, and Jesalmer.

(7.) The total out-turn of work of the season is as follows. Principal observations were taken at 9 principal stations forming a double polygon, fixing 5 new principal stations, embracing an area of 311 square miles and extending the series 21 miles along the meridian to its completion and junction with the Sutlej Series. A secondary series, double throughout, was selected and observed on the meridian of 71° 15′, extending 142 miles from the Jesalmer Minor Series to the Karáchi Longitudinal Series, and covering an area of 2,526 square miles, fixing 16 new secondary and a large number of intersected points. The observatory and telegraph office at Deesa were connected with the triangulation by a short series. All this secondary work was done with a 10-inch theodolite. The approximate work of the Eastern Sind Series was commenced and extended for 134 miles. 32 stations were selected and 10 built.

(8.) This season, seeing as it did the completion of one series and the commencement of another, cannot be judged by the amount of principal triangulation turned out; but the work done this year will, I trust, make itself felt in the out-turn of next year.

(13.) Mr. Price on leaving Ábú was employed on the Deesa connection, and unfortunately took his party up Jeraj H. S., the result being that both he and all his men were attacked by fever and with difficulty reached Deesa, where they had to remain for a month under medical treatment. He then marched to the southern portion of the Eastern Sind Series, and took up the approximate work. This he pushed on with his usual vigour and success, and selected 24 stations and built 8, extending the series 110 miles. This amount, considering the time lost by sickness, was very creditable to him.

(14.) Mr. Torrens was first employed on the Deesa connection which he completed, except the observations on Jeraj, which I directed should be postponed until the end of the season. He then took up the Balmer Minor Series on the meridian of 71° 15′ and selected, built, and observed along it. As it is 142 miles long and double throughout, I consider that Mr. Torrens has done a most creditable season's work.

(15.) Mr. Prunty accompanied me as observatory recorder, and on the completion of the series closed 13 stations and observed at several of the auxiliary stations necessary for fixing the Bahawalpur Revenue Survey stations. He then joined me and aided in the ray clearing &c., on the Eastern Sind Series. During the recess he observed some triangles on Mount Ábú, required to fix the position and height of the barometer which has been lately placed here by Mr. Chambers, the Meteorological Reporter of Bombay. This is the first season he has tried any triangulation, and I am much pleased with the results.

VI. Extract from the Narrative Report—dated 31st October 1876—of Captain A. BAIRD, R.E., Assistant Superintendent 1st Grade, in charge of the Tidal and Levelling Party.

Work performed during recess.

(2.) The curves of the tidal diagrams were carefully compared with the different records and in one or two cases of small interruptions in the work the curves were interpolated by a reference to the daily reports of the sub-surveyors and the inspection books. The computations at first made were those for correcting the tide-gauge clocks to true mean local time at each station for each day during the period of performances of the clocks. The determinations of the zero (and this in some cases for several diagrams of the self-registering tide-gauge) were calculated, several other minor computations were made, and then the position of the pencil for each hour, on every sheet, was corrected to true mean time throughout the entire period required; and finally the measurements of every point from the datum were most carefully made (this in duplicate). Some idea of the magnitude of this work may be formed when I state that over 30,000 points were corrected for time and nearly 30,000 final measurements were made in duplicate. Each final measurement was taken to the nearest hundredth of a foot, and as this gave an average of 4 figures for each distance the summations for the final results were heavy indeed.

You are aware that the observations at Nawanár tidal station were incomplete; however I have been enabled to eliminate almost perfect values for 1½ complete lunations to the nearest hour in 1874

viz., 9h. 1st May 1874 to 14th June 1874 (astronomical time) both hours inclusive; also 2 complete lunations to the nearest hour in 1875 *viz.*, 13 h. 7th March 1875 to 8 h. 5th May 1875, both hours inclusive. I have also tabulated the values for Okhá tidal station and Hanstal tidal station for the same period and have computed the value of mean level of the sea in each case. The following table shows the results of the different computations.

	Correct value of mean level of sea above datum by 12½ lunations.	Mean level of sea above datum by 2 lunations in 1875.	Difference from correct value of mean level of sea.	Mean level of the sea above datum by 1½ lunations in 1874.	Difference from correct value of mean level of sea.	Mean level of sea above datum by 1½ lunations greater or less than by 2 lunations.	Final value of B.M.A above mean level of sea.
At Okhá Tidal Station ...	9·65	9·75	+ 0·1	9·90	+ 0·25	+ 0·15	+10·424
„ Hanstal „ ...	16·33	16·33	0·0	16·51	+ 0·18	+ 0·18	+ 9·702
„ Nawanár „ ...	...	15·36	...	15·56	...	+ 0·20	+ 9·476

You will observe that the mean level of the sea for Okhá tidal station as determined by 1½ lunations in 1874 is 0·25 foot higher than the real value, and for Hanstal similarly it is 0·18 feet higher. Also for 2 complete lunations in 1875 the mean level of the sea is only 0 10 feet higher than the proper value for Okhá tidal station while at Hanstal it absolutely agrees. All this bears out what you state in your No. $\frac{4}{71}$ dated 20th January 1875 *viz.* "you will see that it is very probable that a series of tidal observations embracing a period of 2 months from about the 7th March to 7th of May will give a result very closely coinciding with the mean of the year," and on this account every effort was made to get the observations for that period, and with success. You will also observe that the difference of mean level of sea at Okhá by 1½ lunations is 0·15 feet higher than by 2 lunations: for Hanstal it is 0·18 feet higher, and for Nawanár 0·20 higher—results which alone show the greater accuracy of the observations.

(3.) I determine the M. L. of the sea to be

feet

for Nawanár = 15·36 above datum = 9·476 below B.M.**A**,
„ Okhá = 9·65 above datum = 10·424 below B.M.**A**,
„ Hanstal = 16·33 above datum = 9·702 below B.M.**A**,

The leveling operations show the following results:

B.M.**A**, Hanstal, is 0·41 feet above B.M.**A**, Nawanár;
B.M.**A**, Okhá, is 0·151 feet higher than B.M.**A**, Hanstal;
Okhá B.M.**A** = 10·424 above mean level of sea;
Hanstal B.M.**A** = 0·151 below Okhá B.M.**A**, by leveling;

therefore Hanstal B.M.**A** = 10·273 above mean level of sea by leveling;
but Hanstal B.M.**A** = 9·702 above mean level of sea by tidal observations;

Discrepancy = 0·571

that is mean level of the sea as determined for Hanstal tidal station is 0·571 feet higher than that determined by leveling from the mean level of sea at Okhá.

B.M.**A**, Nawanár = 9·476 above mean level of sea;
Hanstal B.M.**A** = 0·419 above B.M.**A**, Nawanár by leveling;

therefore Hanstal B.M.**A** = 9·895 above mean level by leveling;
but Hanstal B.M.**A** = 9 702 above mean level of sea by tidal observation;

therefore discrepancy = 0·193

that is mean level of sea for Hanstal station as determined by tidal observations is 0·193 higher than that determined by leveling from Nawanár.

(4.) In para. 4 of your No. $\frac{49}{1433}$ dated 30th November 1875, being a reply to my letter above quoted you state "one or other of your tidal stations must be selected as the datum of your leveling operations, and Okhá from its situation nearest the sea is evidently the one to be selected for this purpose."

The mean level of sea at Okhá Tidal Station taken as datum of all leveling operations.

The datum for the leveling operations having thus been settled I was enabled to finish the whole of the abstracts of the leveling operations of the preceding field season.

Peculiarity of levels of the Runn.

(5.) In a previous communication I have stated "you will observe how well the trigonometrical heights agree with the real values, but in Cutch they seem to be all less while in Kattywar they are greater than the values determined by spirit leveling. One very interesting result of the leveling is that the mean value of the Runn between Mallia and Shikárpur is 6·781 above mean level of the sea while between Hanstal and Balumba and Jorya the level of the Runn is 9·525. Now the tide at Hanstal frequently in the cold weather rises to 8 feet above mean level and yet the Runn between Mallia and Shikárpur is perfectly dry from November till March. This shews that there must be a rise in the Runn between the line Mallia-Shikárpur and the head of the Hanstal creek."

Mr. Rendell and Damoder Ramchandra instructed in leveling.

(6.) While these computations were being completed Mr. Rendell, who had been on one month's privilege leave, joined me at Jorya on the 22nd November. After I had given him a practical insight into the method of leveling as carried out in this department, and had satisfied myself that he was *au fait* at the work, and that Damoder Ramchandra the second leveler who was to accompany him was also fit to take up the work, I started them off with their party of men to commence from Shikárpur bench-mark, in Cutch—one of the main points connected in the former season's work.

Comparison of staves &c.

(7.) The whole of the leveling staves were compared with the standard bar, and observations were made for determining the index error of the prismatic compass in each level.

Range of the leveling operations.

(9.) The lines of levels to be executed were as follows. The main line was to be taken right across Kattywar from Jorya bench-mark to Wadhwán, the terminus of the B. B. and C. I. Railway, and thence along the railway line to Viramgám, Ahmedabad, and as far beyond as possible. This work I laid down for myself and a second leveler: of course branch lines were to be driven right and left of the main line to connect the trigonometrical stations. A loop line was to be carried by Mr. Rendell from Shikárpur bench-mark to Addysir both in Cutch; then, crossing the small portion of the Runn to the Chorar and thence into Guzerat, to be taken along the borders of the Runn to Pátri terminus, and finally to join up with the main line at Viramgám bench-mark: the small branch line to Khárághora salt works was also to be leveled over. As I was doubtful of the amount of work which Mr. Rendell and Damoder could perform, this being their first season on leveling, and also as I could not calculate how much even 2 experienced levelers could do with the small new instruments which had lately been supplied, I left the matter of the further work of the second party in abeyance for the time being.

The instruments employed.

(10.) I worked the rectangular level throughout. The cylindrical level worked by Nursing Dass is also a first-rate instrument. The two small levels lately sent, and to be worked by Mr. Rendell and Damoder, were of a new pattern, by Cooke and Sons of York. Mr. Rendell says of them "at times during the cold weather they gave a little trouble on account of the inactivity of the bubble." The limiting distance for the small levels I fixed at 6 chains, and Mr. Rendell reports "at this distance in the cold weather ·001 of a foot was easily readable, but in the hotter months it was almost impossible to work at even a distance of 4 chains after 8 o'clock in the morning.

The main line of levels.

(11.) The main line emanated from Jorya bench-mark, on the main line of the series Hanstal tidal station to Okha tidal station; thence it was carried to Dhrol; the line was then taken along the made-road to Liala; thence to Pardhari and Rájkot: at Rájkot the following paka points were connected—English Church, High School, Rájkumár College. From Rájkot the line was continued along the main road towards Wadhwán as far as Kuarwa, and from this a branch line was taken to Khakhana H.S.; leaving Kuarwa the line was carried still along the main road, *viâ* Bamanbor to Chotila, and here another branch line was driven to Tarkia H.S. The line then continued to Dheduki, and from thence *viâ* Dulia to Muli, whence it was carried along the main road to Wadhwán Railway Station. Leaving Wadhwán the line was taken along the permanent way of the B. B. and C. I. Railway to Viramgám, a branch line being taken from Lilápur bench-mark to connect three minor triangulation stations of the Kattywar and Guzerat Surveys, and on to the head of the Nal river. From Viramgám the main line continued to Ahmedabad and thence to Mehmadabad.

Bench-marks and paka points on the main line.

(12.) As a rule the bench-marks were embedded at 10 miles apart. There were few paka points between Jorya and Rájkot but between Rájkot and Wadhwán the parapets of the bridges on the main road were used. Along the railway as a rule I connected one of the bridges every day. The bench-marks embedded along the line of railway were invariably built close to the railway station except at Viramgám, where the sub-surveyor made a mistake and built close to the wall of the town. The level of the rail opposite the centre of the booking office at every railway station was also determined to test the accuracy of the railway levels.

(13.) At Ahmedabad the Sábarmati was crossed just above the site of the old railway bridge (the new one was under construction). The level of the bed of the river was determined; also a paka point at the Sháhibág was connected, and a bench-mark laid down between the two minarets at the railway stations. The flood line of last year as shewn me was over 40 feet above the bed of the river close to the Sháhibág.

Levels at Ahmedabad.

(14.) The line passed over in Kattywar was very undulating but with a gradual rise from Jorya to Rájkot, which is a little over 400 feet above the mean level of the sea. There are few streams of any consequence, except the Aji river at Pardhari, on this part of the line. From Rájkot the road continued to rise steadily for about 35 miles until the maximum height along the main road was attained at Molri-nana which is 713 feet above mean level of the sea. The country just before this, *i.e.* from the Bedti river to Bamanbor, was very hilly and rugged and entailed a great deal of extra labour, in that so many more stations per mile were required. Near Bamanbor the country is not much cultivated and I believe that 20 years ago this part of the country was covered with dense forest, and that lions were found there. There is no trace of the forest now except a stunted tree here and there, but a great deal of grass is cut and stored here and sent to Rájkot. From Molri-nana to Chotila the descent begins and continues rapidly to Dulia, and from Dulia to Wadhwán the country is tolerably flat and cotton is greatly cultivated. The sudden change in the appearance of the country along our line, from Kattywar where there are few trees of any kind and hardly any large ones, to the heavily wooded country near Viramgám and all along to Ahmedabad and Mehmadabad, is most marked. Then again the ground seemed much more highly cultivated as the line passed through the Ahmedabad collectorate, and the demarcating hedges of the fields often grow to great heights, the general effect of which contrasts strongly with the open country between Wadhwán and Viramgám.

The general appearance of the country along the main line.

(15.) Some of the minor triangulation stations connected were almost entirely demolished.

The minor triangulation stations connected.

(16.) Mr. Rendell reports "the country between Shikárpur and Addysir is very low and flat except near Khanmir where it is crossed by a small range of hills running in a north-west and south-easterly direction. The soil is sandy and very barren-looking: cotton is grown here and there in small quantities, but by far the greater portion of the land is allowed to remain waste, the soil being so poor that it is not worth cultivating. There are no wells in this part of the country and the drinking water is collected in tanks during the rainy season." When Mr. Rendell arrived at Addysir he says "I was surprised to learn that the portion of the Runn which divides Cutch from the Pálanpur State and which I had to level over was covered with from one to two feet of water, and as it was necessary that the level of the surface of the Runn should be obtained, I had to devise means to secure this result."

The loop line Shikárpur to Viramgám.

(17.) Mr. Rendell reports "accordingly I had several long pegs made up for the staves to rest upon: these pegs were driven into the ground up to a certain mark, and this distance from the mark to the top of the peg being known it was easy to get the level of the ground below. To isolate the instrument wooden pegs about 5 feet long were used; these were driven into the ground, their tops being flush with the surface of the water; on these the level stand rested, and I arranged that after I had read the staff the second leveler should read the bubble: in this way I am glad to say I managed to get over this difficult bit of ground and with very good results. There are no bench-marks in the Runn, but one has been laid down on the border at the east end and another at the west end of the line. The line of levels was taken as straight as possible in order that it may be leveled over at any future time. This portion of the Runn is not flat but concave having a depression of about 2 feet at the centre".

Arrangements for getting value of level of the Runn.

(18.) Mr. Rendell continues "having leveled across the Chorar where 2 bench-marks were laid down and connected, *viz*: at Piprala and Sántalpur, I closed my leveling in an easterly direction on Gokatar bench-mark: from this point the line of levels was taken direct to Pátri. A good portion of the ground passed over between Gokatar and Pátri consists of salt waste, the line being near the borders of the Runn. The portions under cultivation were of a loose sandy nature. From Pátri to Viramgám the leveling was carried along the railway line. The top flanges of the iron girders of all the bridges were fixed as well as the height of the rails at nearly all the level crossings."

Across the Chorar to Pátri and Viramgám.

(19.) On the completion of the loop line I instructed Mr. Rendell to run a branch line from Sahij S. and Rarú S. to Mehmadabad bench-mark, which I hoped to reach before he completed the branch line, Kaira S., Kaira Church, and the mile pillars along the main road from Kaira to Mehmadabad were connected. The Sábarmati and Wátrak rivers were crossed on the branch line: there was very little water in either at the time, and the levels of the beds of the rivers were determined.

Branch line from Sahij S. and Rarú S. to Mehmadabad bench-mark.

(20.) On Mr. Rendell's joining me at Mehmadabad the party with the camp equipage proceeded by rail to Surat.

Health of the party.

(21.) On the whole the health of the party was good during the last field season; in fact I may say I was the only one in the party who suffered from ill health, having had a succession of persistent attacks of fever during the whole of it.

Accuracy of the work.

(23.) The loop line emanating from Shikárpur, and closing at Viramgám, formed with the main line a circuit of about 400 miles, and the closing difference at Viramgám was 0·536 feet. On account of the greater power and smaller correction for dislevelment of the larger instruments I have considered the values of the main line to be absolutely perfect, and the difference 0·536 feet to be generated in the loop line, giving an error 0·004 per mile nearly which, considering the instruments they were using and that they had to cross the Runn when covered with water and that this was their first season's work, I consider very creditable to Mr. Rendell and his co-leveler Damoder Ramchandra. As an instance of the accuracy of the work which is done by the larger instruments worked in the rigid manner adopted by this department I may mention the following circumstance. In doing the back section Viramgám bench-mark to mile post 353 a discrepancy of one foot was discovered between the values of the white and black faces as obtained by the cylindrical level. I sent off Nursing Dass to commence from the far end, and I started from Viramgám bench-mark. On joining up and reducing we obtained a result which differed from the previous values by only 0·003 feet, or about 0·0005 feet per mile.

Personnel of the party.

(24.) Mr. Rendell has worked well throughout the entire field season. He reports very favorably on Damoder Ramchandra: of Venayek Narayen, Mr. Rendell reports that he worked hard and that he is a quick and accurate recorder and computer; and of Dhondu Venayek he says that he gives promise of becoming with a little practice a useful and efficient hand. Nursing Dass has as usual worked well throughout the field season, and Bulwant Appaji has also performed his duties in a very satisfactory manner. Sitaram Yeshwant has worked hard but he is by no means a careful recorder nor a correct computer.

(25.) I stopped field work in April, took the office to Surat, and commenced the reduction of the meteorological observations taken at the tidal observatories. The graphical measurements from the anemometer sheets were all completed.

Some of the results obtained by last season's leveling.

P.S.—(By Major Haig). By comparison of the principal and minor stations connected, it is found that the values of the principal stations as determined trigonometrically are from 2·5 feet in defect to 9·2 feet in excess of the values by spirit leveling, and the secondary stations from 2 feet to 27 feet in excess. The average error of the trigonometrically determined height of all the stations connected during this field season is 6·8 feet too great. The heights of the rails opposite the booking offices at 15 railway stations have been determined this season, and the values as given by the railway authorities are from 4·8 feet to 8·8 feet too great, or an average of + 6·9 feet—errors which are not high considering the method of procedure by which they have been obtained as compared with the rigidly accurate system of this Survey.

VII. Extract from the Narrative Report—dated 6th October 1876—of Captain W. M. CAMPBELL, R.E., Officiating Deputy Superintendent 2nd Grade, in charge of the Astronomical Party No. 2.

(1.) My last report, so far as it referred to the electro-longitude operations, was chiefly a description of the alterations then being carried out in the equipment, which at the date of the report were not quite complete. I shall commence this narrative by remarks on the completion and results of these changes.

Transit Telescope No. 2.

(2.) The experience of the past season's operations proves, that the old failings of transit telescope No. 2 have been entirely removed by the repairs which were executed by Mr. Doderet, Mathematical Instrument Maker to the Madras Government, and its line of collimation is now quite as trustworthy as that of the sister instrument. It is still inferior to the latter as regards the Bohnenberger eye piece, which is of too low a power.

Chronographs: new arrangements.

(3.) The alterations of the chronographs were just completed in time for the opening of the field season and have, I am glad to say, proved entirely successful. The saving of time, trouble, and worry by the new as compared with the original arrangements can only be appreciated by one who, like myself, has gone through a large amount of work with both. The loss of a signal now, owing to any defect in the local arrangements, is a thing almost unknown, and to effect this a minimum of attention is required. Under the original arrangement,

I think I am within the mark in saying that, with constant trouble, it was very difficult to obtain a satisfactory record of nine-tenths of the work done.

Modification of new arrangement.

(4.) While on this subject I may mention that the early experience of the field season led to a modification and simplification of the arrangement with which we began. Under my first arrangement each pen magnet was worked, under all circumstances, by a relay of the kind used in the Telegraph Department, four of which I had been able to procure on loan through the kindness of the Director General of Telegraphs. The object of this was to obtain as much uniformity as possible, and to subject all signals, local and line, to as nearly as possible the same conditions as regarded retardation; but on the other hand there was some loss in simplicity. The relays also, being intended for recording signals received through a long wire, were ill adapted for local work with small battery power, and we found that when called on to perform both duties alternately, they required a good deal of attention—the only point on which the electric parts of the chronograph gave any trouble.

(5.) The modification referred to above was carried out after the completion of the first measurement, and consisted of discarding the relays for all local work, and using them only for transmitting and receiving line signals. The pen magnets are now placed locally in simple circuits passing through clock or observer's key at pleasure, and worked by weak batteries. The line signals are received through a relay, which works either pen by its local battery. The signals transmitted through the line are sent by "translation," *i. e.* a local circuit passes through the "translating" relay which works the line circuit. The object of this was to keep local and line circuits quite distinct, in the case of the clock or observer recording through both on the local and the distant chronographs respectively; because when there is any communication between these circuits great trouble is sure to be caused in order to maintain the proper balance of currents. Another advantage is that when the line signal is sent by translation the conditions at the distant station have no effect on the local work, so that the observer at the former may receive the signals sent, or not—put the line wire to earth, or not—&c., as convenient to himself, without in any way affecting the other station.

Retardation affecting signals.

(6.) The result of the new arrangement is that when a signal is recorded on both chronographs the record on the distant one is affected by the retardation of the line and of two relays, as compared with the local record; whereas when the relays were always used in the pen circuits, this difference between the two signals was due to the line retardation alone; and on this account the change may be looked upon as objectionable.

Accuracy of results compared.

(7.) The best way of comparing the accuracy of the work under the different conditions is, I think, by taking an average probable error of the clock comparisons obtained with the several arrangements. I have carried this out with regard to (1) the original arrangements which existed during the season 1872-73: (2) and (3) my first arrangement, with which we measured one arc last season, using—(2) simple clock comparisons, —(3) comparison by longitude signals (*see* para 17): (4) the modification introduced after that arc and used for the rest of the season. The following are the results, each *p. e.* being obtained from 20 individual values of the clock difference, by simple comparison, or by longitude signals:

Mean of	10	values of *p. e.*	of clock comparison	under system	(1) $= \pm$ ·00164
„	6	„	„	„	(2) $= \pm$ ·00318
„	10	„	„ of comp. by longitude signals	„	(3) $= \pm$ ·00395
„	40	„	„ of clock comparison	„	(4) $= \pm$ ·00163

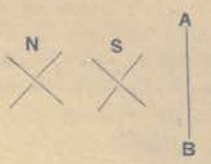
From this it would appear that the accuracy of our latest method is precisely the same as of the original arrangements used in season 1872-73, which is almost beyond my expectation, (*vide* para. 19 of last report), while that obtained by the arrangement with which we began work last season is decidedly inferior. This last result I attribute partly to our comparative inexperience generally, and to the fact that we were trying to use our relays with too small batteries, whence uncertainty of action resulted. These figures indicate also an equality of precision between the methods of direct clock comparisons and of longitude signals. The method of "longitude signals" here referred to is fully described in para. 17.

Collimators.

(8.) I referred to the collimators in my last report as an improvement on those which were used in our work of season 1872-73, and they certainly proved very complete and perfect instruments. It is difficult to judge of the degree of efficiency of the arrangement for ensuring stability of the axial direction, to which I alluded, without placing the new collimators alongside of the old ones and actually comparing their behaviour under similar circumstances, but the new instruments were certainly very stable. We have not had occasion to rely on this stability in order to combine the observations for deviation on different nights, as I thought might be done, because we hit on a method of effecting this much more certainly by means of star observations, as I shall explain in the proper place.

(9) The details of our collimation observations are somewhat novel, and as we found the method most convenient and trustworthy I shall explain it. One collimator, always placed to the north of the transit telescope and called "N", is provided with a fixed cross wire, thus ×. The other, to the south and called "S", possesses a similar fixed × and also a moveable micrometer vertical wire. The × of N was always placed as nearly as possible in the meridian, and that of S a little to one side, so that the appearance in the field of S was as shown in diagram, AB being the micrometer wire. With AB, readings were taken of N and S, and the difference *e* converted into terms of the transit telescope micrometer. Then with the transit telescope each of the crosses N S were observed and the difference *e* applied to the reading of S as a correction. The advantage of the method is that all the observations are exactly similar, *viz*: the intersection of a cross by a vertical wire. The disadvantages are, the necessity for knowing accurately the relation between the micrometer screws of the transit telescope and of S collimator, and the small computation involved in the process; neither of which we found caused any inconvenience.

Method of using the Collimators.



(10.) I shall now proceed to the narrative of last season's operations, in which Captain Heaviside was associated with me. The proposed programme included the measurement of the following arcs, named in the order which we had decided on as the best as regarded the prospects of clear weather and the convenience of my meeting with Captain Heaviside, who had to join me from Dehra Dún, *viz*: Hyderabad-Bombay; Bellary-Bombay; Hyderabad-Bellary; Madras-Hyderabad; Madras-Bellary; Bangalore-Bellary; Bellary-Mangalore, or Madras-Bangalore. Of these the first six were successfully completed, but time did not suffice for the last.

Narrative of field season.

Proposed Programme.

(11.) Captain Heaviside expected to be able to reach Hyderabad about the beginning of December, and I timed my departure from Bangalore accordingly. On 19th November Mr. Keelan started with all the equipment and establishment by road to Gooty (165 miles) whence he proceeded by rail to Hyderabad, arriving there on December 5th. Mr. Bond took the field earlier—on 26th October—for the purpose of finishing some triangulation which he had been unable to complete during the preceding field season, with orders to proceed afterwards to Bellary to select and prepare the longitude station at that place, as also to connect it with the principal triangulation. On 23rd November I left Bangalore and proceeded to Madras, where I had some arrangements to make with Mr. Pogson, after which I went on to Hyderabad, arriving there on 29th November.

Start from Bangalore.

(12.) Hyderabad had always been spoken of generally as the station to be observed at, but nothing could be definitely settled until I reached the place, and had an opportunity of deciding which of the three telegraph offices available in the immediate neighborhood, *viz*: Hyderabad, Secunderabad, and Bolarum, would prove the most convenient for our purpose. A very slight reconnaisance sufficed to decide me in favor of the last named station, which stands on high open ground, with admirable sites for an observatory within a few yards, capable of connection with the principal triangulation by a single triangle, using two stations of the Hyderabad Minor Series which was executed by Lieutenant (now Captain) Rogers with a 24-inch theodolite as an offshoot from the Great Arc. The best site for the station was within the compound of the D. P. W. Office where the Officiating Superintending Engineer, Major Swetenham, R E., kindly allowed me to build the necessary pillars and gave me the use of out-houses close by, which were very conveniently placed for the accommodation of the clock and chronograph. He was also most obliging in obtaining masons and assisting me in various ways.

Bolarum: choice and preparation of station.

(13.) Captain Heaviside arrived on 7th December on which date, although the pillars were not quite complete, there was abundance of employment for him in taking over charge of his party. On the 9th the pillars being ready we began setting up the instruments, and from that day to 28th inclusive we were busily employed in practice observations and in settling the details for actual work, four nights' observations for personal equation being included.

Captain Heaviside's arrival.

(14.) On 29th December Captain Heaviside dismantled, and on 31st proceeded to Bombay, where he was ready to begin the measurement on 10th January. Our first night's attempt proved a failure, in consequence of a fault on the line; but on the 11th we were successful, and we continued the observations with very little interruption from any cause, from that day to the 21st inclusive, which completed the measurement.

He proceeds to Bombay.

Measurement Bolarum-Bombay.

(15.) The programme followed was of two kinds: we began on the old method of season 1872-73 having the line only for certain short periods and using it exclusively for comparing clocks, while during the intervals each took transits with his own clock. I also applied for and on several nights obtained the use of the line for a period of 3 to 4 hours embracing the whole of our programme, on which occasions one clock was used for transits at both stations, changing the clocks in the middle of each night; comparison of clocks being also made at certain intervals. When working on this system a comparison of clocks is not necessary, but it was always taken for two reasons: (1) to obtain a measure of their relative rate, which is useful in determining the absolute rate of each; and (2) because a comparison being obtained it becomes possible to combine transits by each observer with his own clock, in the event of any hitch in the transmission of clock signals for transits, (a case which occurred on at least one occasion) so that such failure does not involve the loss of the night's work.

Programme followed: use of line obtained for long periods.

(16.) In making my preparations for the operations of the field season, when I was only able to reckon on having the use of the wires at certain short periods, I introduced a change in the method of clock-comparison which had been followed by Captain Herschel and myself in 1872-73, *viz*: recording the two clocks alongside of each other for about a minute at a time, which I now call a "simple comparison". My objection to this method was, that unless there is a very great difference between the clock rates (which is inconvenient for other reasons) the record of such a comparison shows no appreciable change, and consequently in transcribing it one reads the same fraction of a second over and over again, which is not conducive to accuracy. I had also in view the prospect of working through cables at some future time, for which purpose clock signals at one second apart would not be suitable, being too rapid, and I wished to introduce and test a system adapted for cable work. Lastly I was influenced by the desire to avoid passing strong currents through the clocks, fearing consequent injury to their break-circuit arrangements, which would be troublesome to repair. On this head I believe my fears were exaggerated, and moreover the use of a translating relay which we adopted soon afterwards, as already noticed, obviates the necessity of passing any but very weak currents through the clocks.

Change in method of comparing Clocks.

(17.) The method adopted I call "comparison by longitude signals",* and it is carried out as follows. The original equipment included observer's keys, capable of making and breaking two separate circuits: these I applied so as to afford two simultaneous signals, one for record on the local chronograph alongside the local clock, and the other for transmission along the line and record on the distant chronograph beside the distant clock. It is obvious that each pair of signals so recorded affords a value of the clock difference, from which the retardation was eliminated by the exchange of signals in alternate directions; and any want of synchronism between the two signals generated by a key was guarded against by reversing its connection with the two circuits. This system answered perfectly in practice, but it entailed more troublesome commutator arrangements, and the record takes much more time to transcribe than that of a simple clock comparison. My object in adopting it was to a great extent satisfied by its successful working, as we have now a proved system of clock comparison to fall back upon in case of finding clock signals unsuitable for transmission to the distant station. When the line was obtained for long periods, the old method of simple clock comparisons was resumed, and I do not think it advisable to depart from it again when working with land lines.

Comparison by Longitude Signals.

Disadvantages.

(18.) At the beginning of the season we started with somewhat complicated commutators, to allow of all the different combinations: these were very greatly simplified by the abandonment of the relays for local work, and the double keys for longitude signals, with great advantage in reducing the chances of mistakes in manipulation.

Commutators simplified.

(19.) On completion of the Bolarum-Bombay measurement, I proceeded at once to Bellary and we began the measurement Bellary-Bombay on 28th January continuing without a check on the three following nights, after which I proceeded to Bombay and we took another set of observations for personal equation with Captain Heaviside's telescope. On my return from Bombay we completed the measurement by observations on 9th and 10th, losing the 8th owing to a fault on the line.

Measurement Bellary-Bombay.

Personal equation at Bombay.

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* This term is very apt: it clearly takes its name from the fact that *if the two clocks were recording true local sidereal times* a single such doubly-recorded signal *would give the difference of longitude*—subject of course to corrections for relay and line retardation—although they are not sent for that purpose. J. H.

Captain Heaviside now went to Bolarum, and the measurement Bolarum-Bellary occupied six nights, 19th to 24th February inclusive. I then proceeded to Madras while Captain Heaviside remained at Bolarum, and we completed the arc Madras-Bolarum on March 12th, being delayed for some days by cloudy weather. Captain Heaviside then moved to Bellary, taking advantage of the opportunity for visiting Madras in order to obtain another value of personal equation. Finishing the arc Madras-Bellary on 2nd April I proceeded to Bangalore and we completed the measurement Bangalore-Bellary on April 18th. The observations on the two last arcs were much obstructed by clouds. The season being too far advanced to permit of our attempting the arc Bellary-Mangalore, Captain Heaviside joined me at Bangalore, and we took a final determination of personal equation with both telescopes before closing the season's observations on April 23rd.

Bolarum-Bellary: Madras-Bellary: Personal equation at Madras. Bangalore-Bellary. Personal equation at Bangalore and close of season.

(20.) Throughout the measurement of the last five arcs we obtained the use of the line wire during the whole of our programme each night, an arrangement vastly superior to the use of short concessions, in many ways:—(1) the dealings with the telegraph officers are simpler, our connection being made once for all: (2) we were able to work by a sidereal time programme, so that exactly the same stars were used night after night—a very great object both as regards trouble at the time and in reductions afterwards: (3) the general reductions of the work will not be nearly so heavy; and, lastly, we have every reason to expect that the results will be superior.

Use of line for long periods always obtained.

(21.) We followed the same programme throughout *viz*: comparison of clocks; transits for forty minutes at each station using the same stars, (to allow of which the transit observation at west station began and ended later than those at east station by a time equal to the difference of longitude); a second clock comparison; transits again for forty minutes; and lastly a third set of clock comparisons. Each observer took level and collimation observations at convenient opportunities, at least two of the former and one of the latter being obtained each night. We used only 15 out of the 25 wires for transits. For the first set of transits E. clock, and during the second W. clock, was used at both stations. In the middle of each group of transits, and also in each set of clock comparisons, the duties of the chronograph pens were exchanged, thus reversing the sign of the pen equation, and eliminating residual error after the application of its accepted value as a correction to the record. The transit telescopes were used equally in the positions I.P.E., I.P.W. at each station, the reversal being effected with great ease, often with hardly appreciable disturbance, by means of a small wooden frame on which the telescope was bodily lifted by four men. Each observer retained the same equipment throughout the season.

Nightly programme.

(22.) As regards azimuth observations, we made a point of obtaining if possible a pair of close polar stars, one above and one below the pole, every night; and the nights on which we failed in doing so were comparatively few. I have now to notice the method of supplementing these observations, to which I referred when speaking of the collimators; a method which so far as I am aware is novel, and according to our experience very valuable.

Observations for azimuth.

(23.) It is often difficult to obtain a pair of well fixed circumpolar stars which occur at times convenient for observation, and moreover in these low latitudes there is always a great chance of losing the lower transit, particularly when the star used is a small one. For the first part of the season δ Ursæ Minoris and 51 Cephei answered our purpose admirably, but their transits became too early for convenience in February. Then there was a short interval during which there were no good stars conveniently available, after which we adopted Polaris *sub polo*, and one of Mr. Pogson's regular azimuthal stars (the data for which he supplied me with), for the rest of the season. This latter star is No. 99 of the Radcliffe Polar List and 4339 B.A.C.

Circumpolar stars.

(24.) The supplementary stars which I call "comparative azimuth stars," are of about 10° N.P.D., chosen simply for convenience of time of transit, and observed every night. The exact places of these stars were not wanted, but only an approximation close enough to permit of their change in R.A. from day to day being computed, for which purpose the places of the B.A. Catalogue (from which they were chosen) are amply sufficient. Now it is, evident that if such a star is observed every night (the observations being corrected for change in R.A.) and an absolute determination of deviation is obtained on any one night by well fixed stars, the deviation can be deduced therefrom for each night. This is an extreme case which never occurred, but we have a few instances of nights on which no absolute determination of deviation was obtained, when it is deduced by means of these comparative stars. After their introduction (February 9 and 10) we made a habit of observing at least two of these stars every night at nearly equal intervals of time from each other and from the circumpolar stars, and these observations have been given their own weight in deducing the mean

Use of comparative azimuth stars.

deviation for each night. Thus it appears that our deviation correction for each night obtained by the above method, depends generally on three or more observations of polar stars taken throughout the night.

Personal equation.

(25.) Our determination of personal equation should be as reliable as such an observation is capable of being. As already noted it depends on the observations of nine nights—two with each instrument before the commencement of the operations; one night with one telescope, and two with the other, during the season; and a night with each at the close of the work. On every occasion the method of sharing transits at the same instrument was followed; that is to say, one observer recorded the transit of a star over the first (generally ten) wires and the other taking his place observed the last ten or twelve wires. The observer who finished one transit always began the next. Twenty such transits were observed on each night, giving a value of the equation with a probable error of about $\pm$ 0·01; the equation itself being about + 0·10, to be applied to Captain Heaviside's observations to reduce to mine.

Personal equation in transcribing chronographic record.

(26.) In the process of transcribing the chronograph record there is probably just as marked a personal equation between individuals as obtains in the observations themselves. This has never been determined, but its effect has been eliminated by taking care that the work of both stations for any one night has always been transcribed by the same person—Captain Heaviside or myself. The same precaution was adopted with regard to the clock comparisons.

Recess work.

(27.) The recess work, including the transcription of the chronograph records and the reductions, is very heavy, so much so that it will be some time yet before we arrive at any final results. The work is however in a very forward state, the whole being brought up nearly equally; and so far as I can form an opinion, the results promise to be satisfactory.

Mr. Bond's work during season.

(28.) I have already remarked, that Mr. Bond began the field season by finishing some triangulation on which he had been employed under Major Branfill's orders during season 1874-75. The necessity for completion was urgent, in order that the whole might be made available for use by Captain Strahan, R.E., in the topographical survey operations which he was then about to commence. I am glad to say that Mr. Bond succeeded in the face of a good many difficulties, arising from weather, an inferior staff of signallers, and the prevalence of cholera in the neighborhood, and handed over all his records to Captain Strahan, by whom I am informed that the quality of the work is excellent. Mr. Bond's work at Bellary proved somewhat difficult, owing to the unfavorable position of the telegraph office, which, combined with the want of good signallers, made the fixing of the longitude station troublesome. He had not quite completed it when I was obliged to send him to Bombay on 13th January to assist Captain Heaviside, in place of Mr. Keelan who was sick. Mr. Bond accompanied Captain Heaviside to Bolarum, and took the necessary observations for fixing the station there, and afterwards completed the work at Bellary. I was disappointed in the progress of his work at Bellary, and making all allowance for difficulties I cannot but think that Mr. Bond's operations there were wanting in judgment and energy. I had a most efficient recorder throughout the season in my native writer Babu Harsahai.

Babu Harsahai.

Personal acknowledgements.

(29.) In conclusion of this report, I have great pleasure in recording my gratitude to the officials of the Telegraph Department for the invariable courtesy with which our wishes were met and acceded to whenever possible. I never applied for assistance of any kind without meeting with a ready and cheerful response, though I fear that our operations must have caused considerable trouble in the different telegraph offices through which we worked, in many cases entailing extra work on telegraph masters and signallers.

To Mr. Pogson, Government Astronomer at Madras, I had frequent occasion to apply for assistance, and I am deeply sensible of the kindness with which he always met my wishes. I fear our work at the Madras Observatory cannot have failed to prove an annoyance to him at times, involving as it did the encampment of my small native establishment in his compound. Finally I would thank my colleague Captain Heaviside, R.E., for hearty and zealous co-operation throughout the season.

VIII. Extract from the Narrative Report—dated 5th October 1876—of Captain W. J. HEAVISIDE, R.E., Deputy Superintendent 3rd Grade, in charge of the Astronomical Party No. 1.

(1.) Having received orders to take charge of No. 1 Extra Party and commence electro-telegraphic longitude operations in association with Captain Campbell, R.E., I left Head Quarters at Dehra Dún on the 17th November and proceeded to Bombay, which is one of the places it was intended to connect.

The Colába Observatory being a fixed trigonometrical station, and connected by wire with Bombay, from which it is about 3 miles distant, its grounds were fixed upon as a suitable place for our observations: it had moreover the advantage of being the place where the pendulum experiments were carried out in 1873 and I had then found Mr. C. Chambers, the Superintendent of the Observatory, so ready to give me every assistance that I felt confident of the cordial co-operation he rendered me in this case and for which my best thanks are due to him.

(2.) Captain Campbell had communicated to me the requirements necessary in the way of space and shelter for the instruments: these are simply an open space for the transit tent, in a position which could be connected by triangulation with trigonometrical points, with an uninterrupted view of the heavens to within 8° or 10° of the horizon north and south, and a room about 10 feet square for the clock and chronograph, conveniently near the transit tent. There were several small buildings on the observatory premises that Mr. Chambers was willing to place at my disposal, and the site eventually selected was 76·6 feet north-east of the trigonometrical station of the Bombay Island Survey. While in Bombay I also visited the telegraph officials and arranged with them about the supply of batteries and the use of the line &c.

(3.) I left Bombay for Secunderabad on the 4th of December arriving there on the evening of the 5th, and on the 7th I moved up to Bolarum where Captain Campbell had selected the station. A day or two later the two transit telescopes were set up close to each other, and the two chronographs with the electrical arrangements were placed in two stalls of a stable which had been prepared to receive them, about ten yards from the transit tent. Between this date and the 28th, I took over charge of the party from Captain Campbell, and we practised work, interchanging signals, taking transits for personal equation, determining values of the micrometer screws, &c., and in general practice in the manipulation of the instruments which were new to me. I am much indebted to Captain Campbell for the instruction he gave me regarding the various instruments and their working.

(4.) Mr. Keelan left Bolarum on the 20th December to build pillars and to prepare the station at Colába, and as the Christmas holidays were impending I gave him a letter to Major Merewether, R.E., Executive Engineer Bombay Defences, who kindly sent a contractor to undertake the work and subsequently checked the contractor's bill for me. The instruments and camp equipage were sent off to Bombay on the 30th of December and I followed the next day.

(5.) The equipment did not reach Bombay until the 4th of January but the interval of three days was fully occupied in making final arrangements regarding the use of the line, and batteries, and seeing to the various connections. There are two telegraph lines between Colába and Bombay: one from the observatory is connected with the clock and time-ball in the Fort, the clock there being regulated by the observatory clock; the other wire leads from the Colába Lighthouse to the Head Telegraph Office in Bombay, and is used to signal the arrival of steamers and other matters connected with the shipping. It is the latter wire that was employed for our work, a switch being placed in the clock room through which the signals from the lighthouses to the telegraph office passed, with a key which enabled me to throw the lighthouse out of circuit and bring our local wire into circuit. At the head office the wire from Colába was connected direct with the wire to Bolarum and the line Bolarum-Bombay was then worked by a battery at each end controlled by Captain Campbell and myself. The battery I had at Colába consisted of 43 Menotti cells, a strength recommended by the telegraph officials, but after our first night's experience we found 20 cells amply sufficient for our purpose. The earth wire at Colába led to a good copper plate which was sunk near a well close by and kept constantly moist. In carrying out these arrangements we are much indebted to Mr. C. E. Pitman, Assistant Superintendent of Telegraphs, in charge of the Bombay office, whose courteous assistance, rendered often at considerable personal inconvenience, tended in no small degree to the smoothness with which our work was carried on.

(6.) Regular work was commenced on the night of the 10th January, and it was rather disquieting after all our practice to fail as we did. This failure was due partly to our working with a line battery too strong for the relays which were adjusted for the local batteries, and partly to a fault in the line; but after this first night we were singularly free from even small irregularities of action. The distance Bolarum-Bombay is almost exactly 500 miles and the line was worked from Colába with 15

cells. During the progress of the work on this arc we obtained the use of the wire on two or three nights for three consecutive hours instead of for periods of a quarter of an hour at intervals of one and a half hours, and this of course considerably facilitated the operations.

(7.) Mr. Keelan, who had been suffering for some time from inflammation of the eyes, was obliged to take sick leave at Colába from the 13th to the 31st January, and it seemed probable that the work would have to be stopped for two or three days until Mr. Bond's arrival from Bellary, but Mr. Chambers kindly lent me the services of his head-writer, by name Huri, who was accustomed to transit work and whom I found an excellent recorder.

(8.) The arc Bolarum Bombay was finished on the 21st of January, and while Captain Campbell was moving to Bellary I employed myself in re-determining the wire intervals of the transit instrument by transit of circumpolar stars, the last determination having been made in 1872, and in checking the connection of the longitude station with the trigonometrical point.

(9.) The arc Bellary-Bombay 526 miles in length was worked from Colába with 20 cells and was completed on the 10th of February. I then moved to Bolarum commencing work there on the 19th of February. The arc Bolarum-Bellary was finished on the 24th of February and the arc Madras-Bolarum on the 12th of March. While the equipment was being moved to Bellary I went down to Madras to take some observations for personal equation with Captain Campbell, and I returned to Bellary on the 24th. The arc Madras-Bellary was completed on the 2nd of April; and Bangalore-Bellary on the 18th.

On the 20th I left for Bangalore, where Captain Campbell and I took further observations with both transit telescopes for personal equation, and this completed our field season.

(10.) The early part of the year was very favorable for star observations, the nights being singularly free from clouds up to the middle of March. Subsequent to that date we were a good deal troubled by cloudy nights, and the weather at Bellary in April had much the character of an incipient monsoon.

(11.) Captain Campbell in his report has entered fully into the system he adopted to carry out the work and the arrangements of the commutator and batteries connected therewith, so that there is but little left for me to relate on this subject. I think however he has hardly done himself full justice in detailing the improvements he has effected, in various ways, but more especially in the chronograph records. By removing the styles which were formerly employed to record the signals by the action of currents of statical electricity on chemically prepared paper, and using in their places pens which draw continuous ink lines on ordinary paper, while the batteries (Menotti's) are in circuit, and which are jerked outwards whenever the circuit is broken, he has not only got rid of the necessity for preparing the paper chemically and for keeping it of a certain degree of dampness—which, it appears, proved such a fertile source of annoyance in the season of 1872-73—but has also effected a great improvement in the distinctness of the recorded signals and in the ease with which they can in consequence be read off. It is very evident too that by getting rid of the Bunsen battery, which is spoken of by Captain Herschel in his report of 1872-73 as "perhaps the most troublesome and provoking source of failure", and by changing the relays formerly in use for others of an improved pattern, Captain Campbell has very much increased the certainty of record of all signals, without, it would appear, any detraction on the score of accuracy. In fact where there are so many sources from which hitches may arise, it more than surprised me to find things work so smoothly that throughout the season it has been quite the exception to lose a signal of any kind; and where losses have occurred, these have almost invariably been due, with me, to the entire stopping or to the very irregular rate of the chronograph, the performances of which, though good on the whole, are occasionally very puzzling.

(12.) In observing transits and determining collimation I have of course adopted the same systems as Captain Campbell describes in paras: 21 and 7 of his report; and in all other respects his systems of procedure have been followed by me. The dislevelment of the transit instrument has been invariably read by the micrometer head from the reflection of the wires in a trough of mercury.

(13.) During the field season Mr. Keelan was chiefly employed in the observatory; keeping a record of the collimation and level observations, noting the stars observed and the number of wires they were observed over, and warning me of the setting and times of transit of the stars. He prepared the station at Colába for the observations and connected it with the trigonometrical station. He has worked both in the field and during the recess with the care and industry that I have invariably found him bestow on his work, and his knowledge of delicate instruments has on several occasions proved of assistance to me.

IX. Extract from the Narrative Report—dated 23rd November 1876—of Captain H. R. THUILLIER, R.E., Officiating Deputy Superintendent 1st Grade, late in charge of the Kumaun and Garhwal Party.

The establishment of the Kumaun and Garhwál Survey Party, up to the time of my last report, had been broken up into two detachments, one operating in the higher snowy ranges of Kumaun and Garhwál and the other in the Dehra Dún. The area that remained to be surveyed in the former districts was about 1,200 square miles only, but under the directions of the Superintendent, the completion of these operations which are necessarily of a costly nature, was suspended. The party therefore has been concentrated in the surveys of the Dehra Dún and Jaunsár Báwar.

(2.) The strength of the party, which consisted in 1874-75 of three Deputy and Assistant Superintendents with ten Surveyors and Assistant Surveyors, was reduced for the season under review to two Deputy and Assistant Superintendents, and seven Surveyors and Assistant Surveyors; one of the latter of whom was on leave from 15th October 1875 to 15th April 1876.

Distribution of Party.

(3.) The area remaining to be surveyed in the Dún being small, the party was divided into two detachments, one consisting of Messrs. W. Todd, H. Todd and I. Pocock with six Native Surveyors to complete the work in the Dún, and the other consisting of Messrs. Ryall, Litchfield and Warwick with one Native Surveyor to commence the detail survey of Jaunsár Báwar, on the scale of 2 inches to a mile, the triangulation of which had been done during season 1874-75. The field operations of both detachments were commenced about 20th October.

Out-turn of work.

(4.) During the season an area of 562 square miles was topographically surveyed: of this 430 square miles was on the scale of 2 inches to a mile, 124 square miles on the 4-inch scale, and 8 square miles on the 12-inch scale. This area comprises the completion of the non-forest tract of the Dehra Dún district, and also of that portion of Jaunsár Báwar which I was directed to survey. The index maps attached to this report, on comparison with the maps attached to my preceding report, show clearly the extent of work completed by this party; the uncolored portions representing the forest tracts which have been surveyed by the Forest Survey Department under Captain Bailey, R.E., *pari passu* with our operations.

(5.) At the end of February, when in Jaunsár, I was directed by the Superintendent to return to Head Quarters at Dehra for the purpose of relieving Mr. Cole (who was proceeding on furlough) of the charge of the Drawing and Photozincographic Branches of the Head Quarters' Office, and also in order to take charge of the Superintendent's office when Colonel Walker went on furlough. I therefore at that time directed Mr. Ryall to assume the full charge of the detachment working in Jaunsár Báwar. On Colonel Walker's departure, I was appointed to officiate as Superintendent and vacated the charge of the Kumaun and Garhwál Party on the 4th April.

(6.) As Mr. Ryall was engaged on the Jaunsár survey from its commencement, and took charge of the party during the field season, he thus had the opportunity of carefully inspecting and examining the whole of the work there: I leave to him therefore, the duty of reporting on this portion of the survey, and on the amount and quality of the work performed by each of the assistants. I must however state that I carefully examined Mr. Ryall's work in the Amláwa valley and found it very accurate and good.

Topography in the Dún.

(7.) The whole of the topography has been done with the greatest care. Where the ground admitted of it, check traverse lines were run by the European Assistants, to test the accuracy of the work executed by the Native Surveyors: 54 linear miles were traversed for this object. The hill sketching by the assistants was examined by myself and the work was found to be accurately delineated.

(8.) Of the assistants employed in the Dún survey, Mr. Pocock completed the work allotted to him on 23rd February and Mr. H. Todd on 23rd March, when they were directed to join Mr. Ryall in Jaunsár. Mr. Pocock not having had much experience in hill sketching, and the scale he was employed on being new to him, his progress was slow, but his work accurate. The native surveyors finished their work on the 4-inch scale, by the beginning of March, and as they were not sufficiently trained for hill surveying without a chain, they were utilized in completing the survey of the station and environs of Dehra, on the scale of 12 inches to a mile, a work which had been previously commenced for the object of teaching them plane-tabling.

Heights.

(9.) Numerous heights have been fixed by aneroid barometers throughout the season's work, and in addition it was found necessary to determine 38 more heights trigonometrically, chiefly from previously fixed stations.

(10.) The work was principally carried on in the Eastern Dún, where the character of the country as regards varied descriptions of ground was similar to that met with and reported on in the previous year, and was equally tedious and difficult to survey. The Eastern Dún is less cut up by deep ravines than the Western. In the latter, the slopes of the northern spurs extending towards its main drainage channel are much greater, and consequently more water worn; whereas the mountain ranges overhanging the Eastern Dún to the north end more abruptly, leaving extensive flat plateaus, chiefly covered with dense forest. The waters consequently do not run off so rapidly, and hence the existence of large swamps which cause the notorious unhealthiness of the Eastern Dún for six months during the year. Under such circumstances it is not surprising that a very small portion is under cultivation. The flats may be said to range from 1,000 feet to 2,500 feet above sea-level, and the hills to the north to over 7,000 feet.

Remarks on the country.

(11.) The field operations of the Dehra Dún and Jaunsár Báwar survey have been brought to a final close. A large amount of mapping has thus been thrown on the hands of the party; on which subject Mr. Ryall will report.

Extract from the Narrative Report—dated 23rd November 1876—of E. C. RYALL, Esqr., Officiating Assistant Superintendent 2nd Grade, in charge of the Kumaun and Garhwal Party.

(1.) The survey of this sub-division of the Dehra Dún District was commenced on the 22nd of October; Captain Thuillier directing me to superintend the work of the assistants.

Introductory and general remarks on the Survey of Jaunsár Báwar.

(2.) At the commencement of the season, Messrs. Litchfield and Warwick were deputed to assist. The latter however, having been lately appointed to the Department, had had no training in surveying; I therefore kept him with me for some little time to learn his work. Later on Messrs. I. Pocock, H. Todd, and T. Kinney, were despatched to assist me. The first-named on the 23rd of February, the second on the 23rd of March, and the last on the 15th of April, the date on which his furlough for six months expired.

(3.) The area surveyed in Jaunsár Báwar amounts to about 430 square miles; this includes about 20 square miles of overlaps. In addition to this, 72 square miles were surveyed by the Forest Survey Department, making the whole area of the sub-division to be 482 square miles. This quantity exceeds by 139 square miles that given in Mr. G. R. C. Williams' "Historical and Statistical Memoir of Dehra Dún, 1874" page 51, para. 109. Further on, in page 58 of the same book, the area is also given as 219,520 acres or 343 square miles.

(4.) Generally speaking, the rule on apportioning topographical work to the assistants is to confine them to certain parallels of either spherical or rectangular co-ordinates as the case may be. This plan is very convenient in all respects in topographical surveys in the plains, where hills have not those lofty characteristics which exist everywhere in the Himalayas. This method of apportioning work in the survey of the Himalayas has been found very inconvenient; it entails much labour and consequent loss of time. I thought it better therefore to depart from this rule by distributing the work so that each surveyor would have watershed lines as limits to his piece of work. For this reason the index map of Jaunsár Báwar has not been marked off into rectangular blocks, usually called plane-table sections.

(5.) After going over the ground, I thought it advisable to lay down some additional points trigonometrically, which I felt sure would very materially facilitate the topographical work in the lower valleys. These points were laid down chiefly from stations fixed by Mr. L. Pocock in his triangulation of Jaunsár Báwar last season. In addition to this, I determined the positions of 14 points up the Pábar river: this was indispensable for the survey of those remote and detached patches of country about Sansog and Banpur, on the right bank of the Pábar. In all 52 points have been added by me to those determined last season.

(6.) The amount of labour involved in surveying Jaunsár Báwar was much greater than I at first expected. This was due to the various *khats* (proprietary boundaries) and boundaries of forest lands having to be surveyed, which involved the fixing of the very numerous pillars demarcating them.

(7.) In the details of topography, I may here remark that upwards of 1,350 boundary pillars were laid down in Jaunsár Báwar by the party, and the accuracy of their positions is quite in keeping

with the requirements of the scale. The boundary pillars were seldom found in conspicuous places; on the contrary, they were either in thick forest or in hidden nooks and corners; it was therefore no easy matter to lay them down without erecting flags at or a few feet from them.

(8.) In order to lay down the limits of the cantonment of Chakráta, I enquired first of the Executive Engineer on special military works, for information regarding its boundaries, but there was no one in the office who was acquainted with them, and all the information I could obtain from there was a map of the cantonments showing its boundaries. But this map I unfortunately found of little or no use: it was not true to scale in the first place; and in the second, while it professed to give the boundary towards the east of the Chakráta ridge by a contour line marked out by pillars at intervals, I found the pillars as pointed out to me very far from occurring in the same level. On the west, a line had been at one time cut, as I saw slight traces of it here and there for a few hundred feet at a time, but there were no pillars to indicate the general line of boundary on that side. Towards the south however, the boundary was sufficiently defined, and so also towards the north-east portion. My next efforts were directed to the Cantonment Magistrate's office, and there I was more unsuccessful still. I was therefore obliged to confine myself to fixing such pillars as existed at the time of the survey. I am by no means sure that the pillars laid down are in their correct positions as originally marked out, for there was no one with me to represent cantonment interests, and my information as to the pillars was simply obtained through the zemindars whose possessions adjoin those of the cantonment.

(10.) The average height of the peaks in Jaunsár is about 6,000 feet above sea-level; that of Kándah, a strip of comparatively very lofty ranges of limestone, lying between the parallels of latitude 30° 44′ and 30° 49′ or thereabout and extending from the Jumna on the one side to the Tons on the other, is about 8,300 feet above sea-level. Many of the peaks however in this strip are close upon 10,000 feet high. In Báwar, the average height of the ranges is about 6,000 feet above sea-level. The great peculiarity of Jaunsár is the general absence of forests in it. Kándah is rich with foliage of many kinds, principally the oak, rhododendron, spruce fir, deodar, &c. Báwar is also very richly covered with forest, but not quite to the same extent as Kándah.

(11.) All along the banks of the Tons, the Pábar, and the Jumna rivers, the mountains are extremely precipitous; so are also the mountains of the Kándah belt. In other respects, as to minuteness of detail, the three belts of country are not much unlike one another.

(12.) I now proceed to report separately on each Officer's work.

(13.) I marched from Mussooree on the 21st of October, and after having a general look at the country in Jaunsár Báwar, I commenced operations in the Binolgadh valley where I continued plane-tabling till the 2nd of December. I then marched up to Sansog in the Pábar valley for the purpose of executing some triangulation, where I arrived on the 6th. Unfortunately when returning to camp during the evening of the same day I met with an accident and sprained my ankle, which disabled me in consequence from resuming work till the 9th, but on the 12th I succeeded in sending Mr. Litchfield the data for 14 points newly fixed, to enable him to complete the sketching of those small patches of country lying on the right bank of the Pábar. Shortly after I marched into Deoban, where I arrived on the 14th, Captain Thuillier having summoned me in order to confer about the work. I resumed the topographical sketching of the Binolgadh valley on the 16th December and finished it on the 24th. I next took up the sketching of the valley of the Amláwa river down to latitude 30° 35′, as well as a strip of country about 3½ miles broad lying to the east of the ridge which runs down from Deoban to Chakráta and thence to Pokri and Barot.

(14.) On the 26th February, Captain Thuillier arrived at Saiya, where he requested me to meet him in order to make over to me the entire charge of the operations in Jaunsár Báwar. So that in addition to my other duties, that of examining the work of each of the assistants devolved on me. I finished work on the 30th of April and marched back to recess quarters, where I arrived on the 3rd of May.

Mr. C. J. Nouville.

(15.) Mr. Nouville was employed the whole season in the office of the party carrying on the miscellaneous current work, of which there was a large amount. He also assisted Captain Thuillier in the Dún by taking a few vertical observations with a theodolite.

Mr. W. Todd.

(16.) Mr. W. Todd began work on the 13th October on P. T. Section No. 47, of the Dehra Dún Survey, confining himself to those parts of the hills in it which were left unfinished during the previous season. The flat and raviny portions in this section were taken up by two Native Surveyors placed under Mr. Todd. Mr. Todd next took up P. T. Sections Nos. 66, 67, and 68. The two former were entirely mountainous, and the latter partly so. With the exception of a small portion done by Mr. I. Pocock in Section 66, Mr. Todd sketched these three sections. The mountains in these sections range from 4,000 to 6,500 feet above sea level, and there is a geographical peculiarity in them which may be noticed here. The slopes are very abrupt

for a short distance from the main ridge towards the south, and then the spurs run at a comparatively gentle incline, and after that they terminate in a steep fall to the Dún. The middle slopes are cultivated for the most part and have the villages on them; the terminal ends of the hilly spurs and their flat plateau-like continuations are principally covered with sál. Mr. Todd after completing the sketching of the 4 sections above-mentioned took up the sketching of P. T. Section No. 70. The work of the Native Surveyors attached to him was carefully examined by partial lines and found very accurate. Mr. Todd has turned out a fair amount of work, and for accuracy of sketching he has maintained the reputation which he has so deservedly won in the Department. He closed work on 22nd May and I regret to add that on the same day, he was prostrated from exposure to the sun and did not recover his health for some time.

Mr. H. Todd.

(17.) Mr. H. Todd commenced work on the 14th October in P. T. Section No. 56, Dehra Dún Survey, part of which had been surveyed last season. He then took up what remained of Section No. 36, a very difficult hilly piece covered with forest. His next piece of work was in Section No. 59, in which he was assisted by a Native Surveyor for the lower flat portions. This last section was also covered for the most part with forest. He also sketched into Section No. 58 up to the watershed of the Song. The mountains in Section No. 56 rise up to about 7,000 feet above sea level, and in Sections 58 and 59 he had the Kálimatti peak for his highest point which is 4,400 feet above sea level. There was a good deal of detail in the last mentioned sections. After sketching a portion of the forest-clad hill of Nalápáni, Mr. Todd was ordered to join me in Jaunsár, for which place he started on the 23rd March. On his arrival there he took up the sketching of the middle portions of the Khatní river valley, east of Chakráta, the ground in which ranges from 3,500 to 8,500 feet above sea level. This he began on the 28th March, and finished by the 28th of the following month. Mr. Todd worked very hard throughout the season, turning out a large quantity of work accurately done and drawn in a true and artistic style.

Mr. T. Kinney.

(18.) Mr. Kinney reported his return from 6 months' leave of absence on the 15th of April. As there was some doubt as to the possibility of completing the Jaunsár Survey before the setting in of the rains, I thought it advisable to have his help for the short remnant of the field season, and therefore directed him to proceed to Jaunsár to take up the survey of the ground about Shenj, Una, and Bahána villages on both banks of the Tons river. Mr. Kinney began work on the 22nd April and finished by the end of the same month, after which he returned to quarters. He worked with his usual care and artistic skill.

Mr. E. F. Litchfield.

(19.) Mr. Litchfield marched from Head Quarters on the 16th October, and took up his first piece of work which chiefly lies in Sheet No 1 of the Jaunsár Survey, about the valleys of the Tons, the Pábar and Dhárigadh rivers. In this piece he had numerous patches of Government forests, the boundaries between which and the village lands were demarcated by a very large number of pillars. Notwithstanding their numbers, and the intricate nature of the mountains which were for the most part thickly covered with forest, Mr. Litchfield managed to get through this his first piece very creditably. His next work was chiefly on the east of the Tons river up to about longitude 77° 52½', below latitude 30° 42½', and down to the confluence of the Tons with the Jumna river. Mr. Litchfield brought in a very large quantity of work, carefully and well executed. He closed work by the end of April, and marched back to quarters, where he arrived on the 3rd May.

Mr. I. Pocock.

(20.) Mr. Pocock took the field on the 16th October and began work in the Dún in P. T. Section Nos. 48, 58 and a small portion of No. 66. He was assisted in the flat and raviny portions of these two sections by 3 Native Surveyors, who also assisted him in traversing the main watercourses. He completed his work in the Dún on the 23rd February, and marched to Jaunsár where I gave him a small portion of ground lying to the west of the Chakráta and Mussooree road, between latitude 30° 30' and 30° 35' and east of longitude 77° 55'. His next piece of work was between latitude 30° 42½' and 30° 45' east of the Tons river and up to about longitude 77° 54'. Mr. Pocock after finishing the work allotted to him in Jaunsár on the 18th May, returned to quarters, where he arrived on the 25th of the same month. Mr. Pocock worked well and indefatigably.

Mr. R. Warwick.

(21.) Mr. Warwick remained with me about 5 weeks learning his work, after which I sent him to survey a piece of ground about 3½ miles in breadth along the western bank of the Jumna river, between the point of junction of the Rulina river with the Jumna and the suspension bridge on the Mussooree-Chakráta road. The next portion he undertook was to the east of the Tons river and about the village of Kándui. Mr. Warwick worked well and hard. He has the making in him of a first-rate topographical surveyor, and I feel no doubt that he will in the course of a few seasons more, justify my anticipations on this head.

(22.) Six maps in all have been completed during the recess. These are as follows:—

Mapping.

2 Skeleton Sheets Nos. VII and XXIV, scale 1 inch = 1 mile, of the Kumaun and Garhwál Survey; 1 Shaded Sheet No. XXI on the same scale of the same survey, and 3 Sheets of the Dehra Dún Survey *viz*, Nos. VIII, XVI and XXII, scale 4 inches = 1 mile. The mapping has been very much retarded in consequence of Mr. Kinney sustaining an injury by the fracture of his right wrist. His services as a draftsman were lost to me thereby for nearly two months.

KUMAON AND GARHWAL PARTY.

SURVEY OF JAUNSAR BAWAR, DEHRA DUN DISTRICT.

Tabular Statement of out-turn of work. Season 1875-76.

Details of Triangulation.

OBSERVER'S NAME.	Instrument used.	Area triangulated in square miles.	2 Angles Observed				REMARKS.
			No. of Intersected points.	No. of Triangles.	Error per mile.	No. of Heights.	
E. C. Ryall, Esquire, ...	6-inch*	†	52	104	Inches 11	9	* Subtense instrument, one vernier only used. † Over previously triangulated ground, including 25 stations visited.

Details of Topography. Scale 2 *inches* = 1 *mile.*

NAMES.	Area surveyed in square miles.	No. of Plane Table Stations per square mile.	REMARKS.
E. C. Ryall, Esquire, ...	102	10·0	Intricate and about half covered with forest.
Mr. H. Todd, ...	38	6·7	„ „ „
„ T. Kinney, ...	9	6·0	„ but comparatively open ground.
„ E. F. Litchfield, ...	168	8·5	„ and about ⅓ covered with forest.
„ I. S. Pocock, ...	46	7·5	„ „ ⅓ „
„ R. F. Warwick, ...	67	7·7	„ but comparatively open ground.
Total, ...	430 Includes 20 square miles of overlaps.		

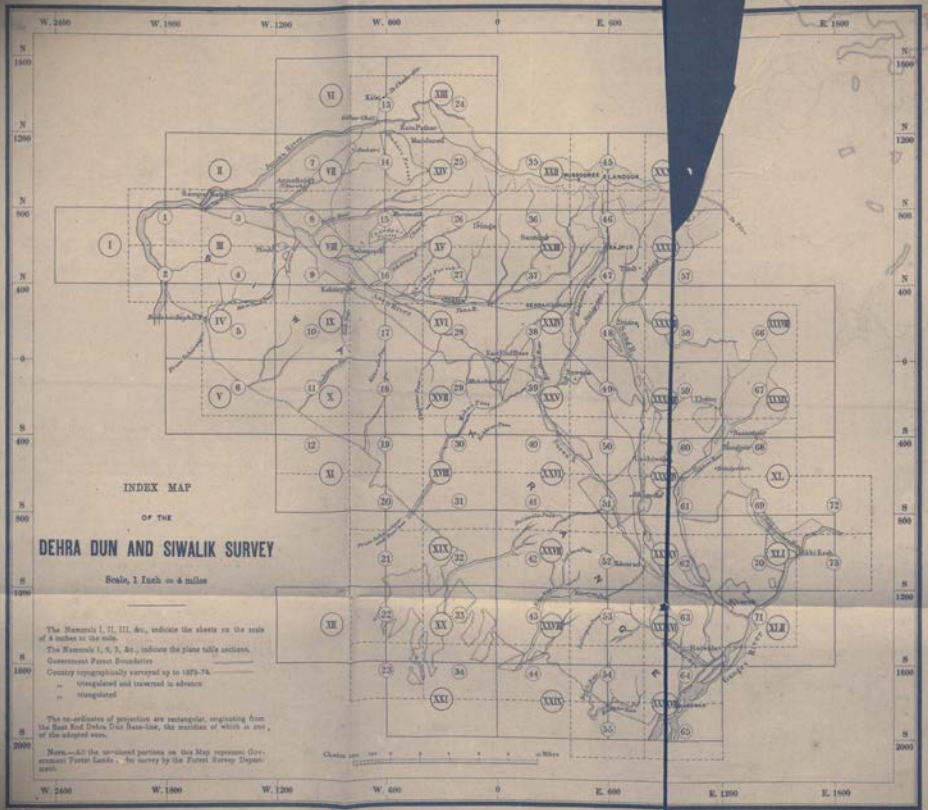
Details of Traversing.

NAMES.	Instrument.	Linear miles of Traversing.	No. of Stations.	Average error per 1000 links.	REMARKS.
One Native Surveyor, ...	*	71·96	1792	2·3	*Card board circular protractor 12 inch in diameter and Needle. Traverse carried along hill roads.
Total, ...	...	71·96	1792	...	

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

Photozincographed at the Office of the Superintendent, Great Trigonometrical Survey, Dehra Dún, November 1870.

GREAT TRIGONOMETRICAL SURVEY OF INDIA.


W. 2400
W. 1800
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S 1200
S 1600
S 2000
Kalsi
Kota Pathar
Mandawal
Lakhwar
Ambadi Rao
Kalsi
Kalsi Rao
Kalsi River
Tons River
Jumna River
Tons
Jumna

SURVEY OF DEHRA DUN AND SIWALIK HILLS.

Details of Topography. Scale 4 inches = 1 mile.

NAMES.	Area surveyed in acres.	No. of Plane Table Stations per acre.	REMARKS.
Mr. W. Todd, ...	18,564	5·4	Mountainous and for the most part covered with forest.
„ H. Todd, ...	19,492	6·4	Mountainous and intricate and for the most part covered with forest.
„ I. S. Pocock, ...	7,534	5·6	Mountainous and for the most part covered with forest.
6 Native Surveyors under the supervision of the above mentioned officers.	33,691	3·0	Flat and ravine ground and in some parts intricate and covered with forest.
Total area ...	79,281 or 124 square miles.		

X. Extract from the Narrative Report—dated 13th September 1876—of Major A. PULLAN, S.C., Officiating Deputy Superintendent 3rd Grade, in charge of the Kattywar Survey Party.

During the recess season of 1875 fair maps of Sheets 31—42, 43 and 44 of Kattywar were prepared on a scale of 2 inches to a mile for publication on the 1-inch scale; and the data connected with Degree Sheet VI of Kattywar were partially prepared. Mr. F. Bell, Surveyor 3rd Grade, worked during the recess season but did not take the field owing to ill health; Mr. Bell proceeded on one year's furlough to Australia on the 1st November 1875.

PERSONNEL.

Major A. Pullan, S. C., Deputy Supdt.
J. McGill, Esq., Asst. Supdt.

Surveyors.

Mr. J. Peyton.
„ N. C. Gwynne.

Assistant Surveyors.

Mr. W. A. Fielding.
„ W. Oldham.
„ G. T. Hall.
„ H. Corkery.

Senior Sub-Surveyor.

Mr. V. R. Gadboli.

Sub-Surveyors.

Govindji Mahalay.
Narsu Dinkar.
and eight others.

The out-turn of work for the season of 1875-76 was considerable. An area of 2253 square miles was topographically surveyed and consisted of parts of Prants Hálár, Kattywar, Sorath, and Jhalawad: 1850 square miles were trigonometrically surveyed in advance, preparatory to next year's topographical operations; and 1600 linear miles of traverse were carried over the different sheets demarcating the taluka and state boundaries and checking the details of the plane table survey.

Departure for the Field.

The party started for the field on the 20th October. The heavy baggage and horses with the subordinate Native establishment proceeded as in former seasons by "patimar" boats to Gogo which port they reached on the 2nd November. Messrs. Hall, Corkery and V. R. Gadboli were sent in advance of the main party to Gogo, and this arrangement saved several days' delay at that port, as they prepared plane tables, projected points &c., so that each surveyor on arrival found his board ready for him and was enabled to proceed without delay to his especial work.

Capt. Pullan, Depty. Superintendent, in charge.

I started from Gogo in company with Mr. McGill on the 15th November and we marched by regular marches to Mánekwára. Here Mr. McGill turned northward and proceeded to take up the triangulation of Sheet 46. I marched west to Junágarh and on arrival there I proceeded to make a careful reconnaissance of the Girnár mountain, that isolated pile of granite being a very remarkable geographical feature. Subsequently I proceeded northwards to Gondal and commenced my examination of the plane tables in Sheet 36. With the exception of a fortnight spent in correcting on the spot the hill shading of a very rugged and difficult portion of country in Sheet 45, my time throughout the field season

was spent in the examination and checking of plane table work. On the 3rd of April I left Gogo on duty to Poona, and after examining the preparation of the fair traverse sheets which were in course of execution, I availed myself on the 8th of April of 2 months' privilege leave and proceeded to Mahableshwar, having made over charge of the party to Mr. McGill, Assistant Superintendent.

J. McGill, Esq.

Mr. McGill executed the triangulation of Sheets 46, 47 and 48 in his usual admirable manner, completing in all 1650 square miles and joined me on my way to Gogo at the end of March. Mr. McGill then remained at Gogo bringing up Angle books and preparing triangle sheets for computation until the whole of the Plane Table Surveyors had completed their work.

Mr. J. Peyton.

Mr. Peyton was entrusted by me with the independent charge of Sheet 10a, the northernmost portion of Kattywar abutting on part of Guzerat to the east and having the Runn to west and north, Nilkant Vital sub-surveyor accompanied Mr. Peyton. Mr. Peyton completed the topographical survey of the sheet and proceeded to Poona to get on with the preparation of the fair sheets. Mr. Peyton himself completed 206 square miles of topography—an out-turn of field work in every way satisfactory.

Mr. N. C. Gwynne.

Mr. Gwynne worked in his usual energetic way throughout the field season. His out-turn of work was 201 square miles comprising the whole of the Girnár range, very difficult ground, sketched in a most artistic and correct manner.

Mr. W. A. Fielding.

Mr. Fielding executed 238 square miles of topography in very good style. Mr. Fielding is always most accurate and reliable and shows great tact and judgment in dealing with Native officials.

Mr. W. Oldham.

Mr. Oldham executed 139 square miles of topographical survey in a creditable manner, a portion of the ground which fell to his share, bordering as it did on the Gir Forests, was full of low spurs thickly clad with trees and small intricate ravines. Mr. Oldham also completed 200 square miles of triangulation (portions of Sheets 40 and 50).

Mr. Geo. Hall.

Mr. Hall's out-turn of work was 204 square miles of topography carefully executed.

Mr. H. Corkery.

Mr. Corkery's out-turn of 206 square miles was highly creditable to him. He has much improved in his mode of delineating ground. The hills being shown in a really artistic and graphic manner.

Mr. Visaji R. Gadboli Head Sub-Surveyor and other Native Surveyors.

Mr. Visaji Gadboli worked steadily throughout in the projection of plane tables and computations of the latitude and longitude of subsidiary points for Plane Tablers. The amount of fair mapping to be done in the recess being unusually heavy, Mr. Gadboli was sent by me to Poona in the end of February and was employed in computing traverses and preparing fair traverse sheets. Govindji Mahalay executed 201 square miles of topography in his usual neat and graphic style. His work was as good this season as in former years. Narsu Dinkar completed 232 linear miles of traverse, the ground being in many places complicated in detail and difficult to chain. Krishna Govind completed 86 square miles of topography. He is a new hand at plane tabling and was very slow, but I found his work carefully done and very correct. Bholoji Bhosekar did a good season's work as a Traverse Surveyor, his out-turn being 289 linear miles carried over a difficult country. Nilkant Vital executed 236 square miles of topography, a large and highly creditable out-turn. Keshu Vital turned out 143 square miles of topography creditably. His work of this season shows a decided improvement on that of former years. Tukaram Chowdry did a good season's work of 211 linear miles of traverse. Ganesh Ramchandra completed 214 square miles of topography in a neat and workman-like manner. Vishnu Balwant executed 179 square miles of topography very well for a beginner. And Lazarus D'Souza acted as recorder to Mr. McGill. He writes a neat hand.

General health of the district.

Throughout the field season, sickness prevailed in Kattywar, fever was rife, and cholera of a sporadic character broke out fitfully here and there. The party was exceptionally fortunate for only three deaths occurred throughout the different survey camps, although men were dying daily in the villages around.

The Girnár Range.

The most remarkable geographical feature in the country surveyed during the season under review is the Girnár mountain and its spurs. This very remarkable granite mass, rising as it does abruptly from the plain, can be seen on a clear day at a distance of 50 miles looming in haze on the verge of the horizon. The mountain lies due east of the town of Junágarh which is at the foot of one of the western spurs.

The highest peak of Girnár, known by the pundits as Ujyant, rises to an elevation of 3,666 feet above sea level; the upper part of the mountain towers almost perpendicularly above the surrounding

spurs some 500 feet, a huge mass of granite intersected diagonally by thin laminæ of quartz; this pile is broken at the summit into three sharply defined peaks, the westernmost and lowest being dedicated to Amba Devi, the middle and highest point to Goraknath, and the easternmost to Datatri Swami; round this great central mass the lower spurs wind and spread inclosing the holy mountain in a circle of hills. The next highest peak on the range is called Datar, and nestling below the granite precipices which crown the mountain is the shrine of Jamil Shah, a celebrated Pir to whose sacred tomb leprous and blind both Mahomedan and Hindu even now journey to be made whole again. One more peak Kalika Tonk may be mentioned, which though lower than Girnár or Datar, still rises to a height of 2,527 feet above sea level and attracts the eye by the grandeur and abruptness of its granite pinnacle. Girnár is held in the greatest veneration both by Brahmin, Jain, and Mahomedan. The most remarkable temples on the hill are Jain and are at the base of Amba Devi peak; they bear date "Sumwut" 1215 or A. D. 1159. As the traveller approaches from the west the sacred "Ujvant" towers above the picturesque town of Junágarh, a blue cone; on nearer approach, the mountain takes shape, and spurs and precipices appear, and enclose a good flagged road the *via sacra* of Surashtra, which leads from Junágarh through a lovely wooded valley by the green waters and temples of Damodar Kund, a haunt of fakirs and monkeys, for some 3½ miles until the foot of the mountain is reached; still there is no break in the road, the broad flagged path winds its way through brushwood and crag and along the face of granite precipices, past the Jain temples of Amba Devi, until it terminates on the topmost point of Goraknath below the hoary time-stained walls of the little temple. Only the most energetic of the pilgrims force their way beyond this point, but a determined few may be seen struggling, with painful steps and slow, over the rugged granite to the lovely little temple of Datatri.

One striking feature on the mountain is an immense perpendicular rock called Bheru Jap, from the summit of which in the days before British rule was established, hundreds of mad devotees threw themselves into the abyss below as a religious act of suicide.

The scenery of this remarkable range is unique. The enormous crags and perpendicular precipices of black granite are tinged here and there with hoary stains of time and exposure. The temples ancient and weather-worn, and the long arms of lower ranges that stretch round and wrap in crag and forest the skirts of the great central pile of Girnár, form a scene of picturesque beauty and grandeur not to be surpassed. The view from the summit of the mountain is wonderful, all Kattywar seems spread out like a map under; and at sunset when the sun's declining rays tinge temple and rock with glowing tints, and the Gulf of Cutch gleams in the horizon like a golden zone, the traveller gazes on a scene perfectly unique and singularly beautiful. The heavy forest and thick underwood which covers the Girnár range is the haunt of numerous Sambar, but they are shy and difficult to come across, leopards also hang about the ravines running into the plains in considerable numbers.

Principal Towns.

The Principal towns in the portion of country surveyed this season are:—

1st, Gondal—the principal town of the Gondal state; the chief is a Jhareja Rajput. The town is on the banks of a small stream a tributary of the Bhádhar, and is clean and well kept: the high road from Rájkot to Junágarh runs through Gondal, and a neat bridge spans the river. The Political Agent's bungalow, Public offices, Post office and Hospital, all well built edifices, combine to give Gondal a remarkably thriving look, and the town is also connected by an electric telegraph line with Rájkot and Bombay.

2nd, Jetpur—this town is the seat of a petty "Katty" chief of the Wala race. It is a walled town very picturesquely situated on the banks of the Bhádhar river over which a handsome stone bridge has just been erected by the Executive Engineer for Kattywar. Behind the town looms in the far distance the Girnár range, and the rapids of the Bhádhar in the foreground, combine to form a very pleasing picture. There is a good travellers' bungalow at Jetpur, and the high road between Rajkot and Junágarh passes close by the town.

3rd, Dhoráji—this is one of the chief towns of the Gondal taluka; it is situated on the south bank of the Bhádhar river and is a large and thriving place: there is a very good school here, and the town is connected *viâ* Jetpur, Gondal, Rájkot, and Ahmedabad with Bombay by a line of telegraph.

4th, Junágarh—this town the seat of a Mahomedan Nawáb, is situated among groves of mango and other trees, a strong wall formerly surrounded the town, but it is now falling into decay, a large fort called Uparkot looks down upon the town, but although formidable in appearance it is now uncared for and deserted. Junágarh with a population of 18,311 souls is inferior only in importance to Jámnagar and Bhaunagar, and ranks as the third town of the province. The town is surrounded on the south and west by heavy jungle stretching for miles, and on the east it is shut in by the lower spurs of the Girnár, the north approach is open and a good metalled road runs between Rájkot and Junágarh. The water supply of the city is bad and scanty. Junágarh is connected by electric tele-

graph with Gondal and Rájkot.

5th, Jhinjhuwára—this is a town of some size whose crumbling walls and massive old gateways indicate former prosperity. Not far from the town and on the edge of the Runn is the island of Jálandar on which are some curious springs of brackish water which bubble up from the ground even in the severest drought. Jhinjhuwára is the residence of a Rajput Thákur, but a Kamdar, deputed by the British Government, administers justice and collects the revenue.

Rivers.

The principal rivers which flow through the country under review are the Bhádhar, the Ujat, and the Ubon. The Bhádhar the most considerable river in Kattywar rises in the low hills north of Jawán and taking a south-western course falls into the Gulf of Cutch at Nawi Bandar. In the rainy season the Bhádhar is said to be navigable for small craft as far inland as Dhoráji near Junágarh. The Ujat rises in two forks in the plateau near Mánekwára and flowing north joins the Bhádhar about 4 miles from Nawi Bandar. The Ubon rises among the northern spurs of the Girnár range and falls into the Ujat at Wauthali.

Appearance and character of the country.

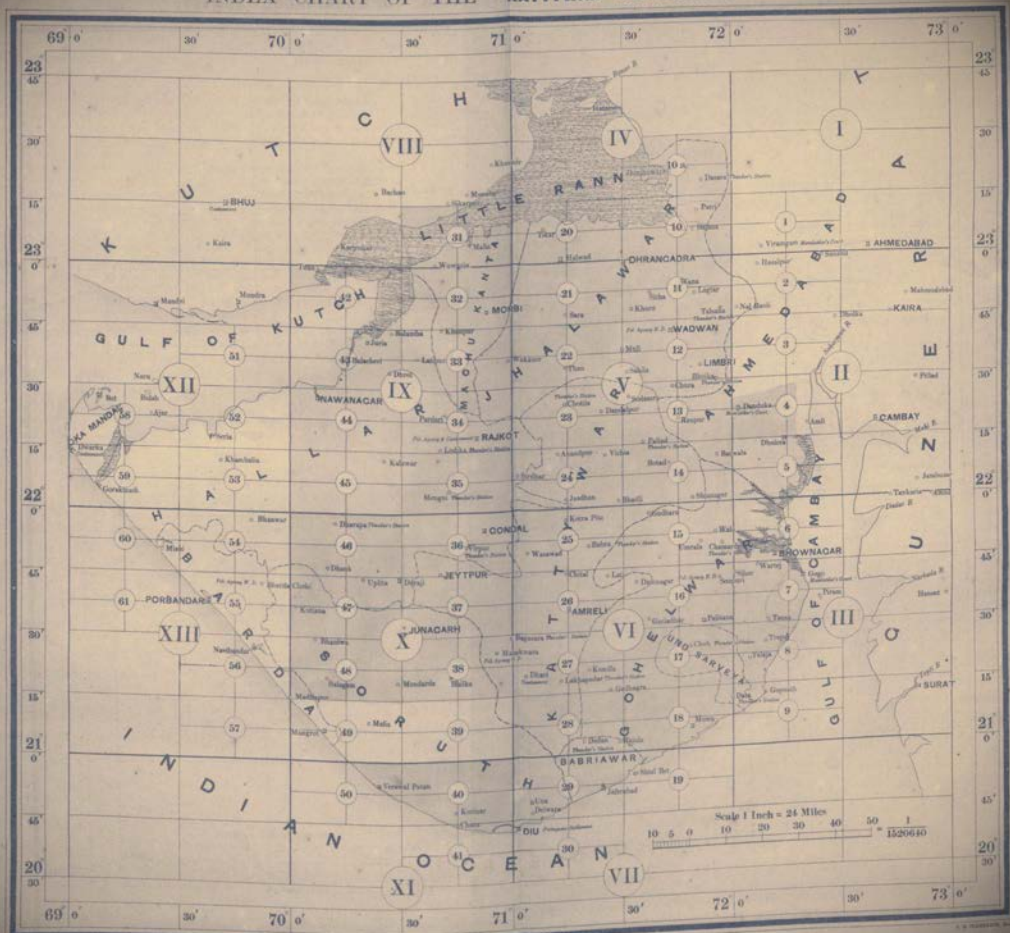
The villages in the portion of Kattywar surveyed during season 1875-76, are decidedly populous, the country being fertile and, for Kattywar, well wooded, mango, tamarind, bar and pipal trees are here scattered over the plain and afford a grateful shade near villages and wells. Fine crops of bajree and cotton are grown throughout these districts, and the sugarcane is also largely cultivated.

Population.

About one third of the people of the Junágarh state are Mahomedans, the remaining two-thirds are Hindus of various castes. In the Gondal state about three-fourths of the people are Hindus, the remainder Mahomedans. Guzerati is the language of the masses, but Hindustani is well understood in all the large towns, more especially Junágarh.

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

INDEX CHART OF THE KATTYWAR TOPOGRAPHICAL SURVEY.



The numerals 1, 2, 3 &c., indicate the sheets on the scale of one inch to the mile. The numerals I, II, III &c., indicate the degree sheets, on the Scale of ½ inch to the mile. The sub-inch sheets are divided into 4 sections known as the N. E., N. W., S. E., & W., portions of the sheet, of these a few copies will be published on the Scale of the original Survey viz., 1 inches to the mile for the use of local officials.

Photozincographed at the Office of the Superintendent, Great Trigonometrical Survey, Dehra Dún, January 1877.

TABULAR STATEMENT OF WORK EXECUTED BY THE KATTYWAR SURVEY PARTY, DURING THE FIELD SEASON 1875-76.

Details of Triangulation.

Observer's Name.	Instrument.	Area triangulated in square miles	3 Angles Observed.					2 Angles Observed.				Average No. of trigonometrical points per square mile.	Average No. of heights per square mile.	Lat. and Long. deductions.	Pillars built.	Remarks.
			No. of stations fixed.	No. of triangles.	Triangular error.	Error per mile.	No. of heights.	No. of Intersected points.	No. of triangles.	Error per mile.	No. of heights.					
					"	*Feet*				*Inches*						
Mr. J. McGill, ...	Cooke and Sons' 7-inch	1650	62	144	12·7	0·48	64	580	1060	1·10	206	0·4	0·2	317	146	
„ W. Oldham, ...	Troughton and Simms' 6-inch	200	12	21	11·8	0·68	13	76	118	1·40	12	0·6	0·1	43	13	
	Total, ...	1850	74	165	12·3	0·58	77	656	1118	1·25	218	0·45	0·15	360	159	

Details of Topography. *Scale 2 inches = 1 mile.*

Name.	Area surveyed in square miles.	No. of plane table stations per square mile.	Remarks.
Mr. J. Peyton, ...	206	10·7	
„ N. C. Gwynne, ...	201	5·6	
„ W. A. Fielding, ...	238	9·7	
„ W. Oldham, ...	139	12·6	
„ G. Hall, ...	204	9·9	
„ H. Corkery, ...	206	9·9	
Sub-Surveyors.			
Govindji Mahalay, ...	201	8·4	
Krishna Govind, ...	86	22·1	
Keshu Vital, ...	143	16·3	
Nilkant Vital, ...	236	12·0	
Ganesh Ramchandra, ...	214	11·4	
Vishnu Balwant, ...	177	12·4	

Details of Traversing.

Name.	Instrument.	Linear miles of traversing.	No. of stations.	Average error per 1000 links.	Average angular error per station.	Remarks.
					"	
Narsu Dinkar, ...	Cooke and Sons' 5-inch ...	465	1273	0·7	9·2	
Bholoji Bhoskar, ...	Troughton and Simms' 5½-inch	629	1311	0·5	7·9	
Tukaram Chowdry, ...	Do. do.	506	1808	0·8	15·8	

XI. Extract from the Narrative Report—dated 30th October 1876—of Major C. T. HAIG, R.E., Officiating Deputy Superintendent 1st Grade, in charge of the Guzerat Survey Party.

(3.) The out-turn of field work consists of 924 square miles of topography on the 4-inch scale and 948 square miles on the 2-inch scale, the former being chiefly British Khálsa land and the latter chiefly Foreign territory; and 1650 square miles were prepared for final survey chiefly by traversing but with a little triangulation where it was necessary.

PERSONNEL.

Major C. T. Haig, R.E.
Lieutenant J. E. Gibbs, R.E.
Mr. A. D'Souza
" A. D. L. Christie
" C. H. McAFee
" J. Hickie
" G. D. Cuxson
" S. F. Norman
" C. Norman

Sub-Surveyors.

Mr. H. G. Ferns
Gopal Vishnu
Bálkrishna Bábáje
Lakshmáji Gharpuri
Ganesh Náráyen
Ganesh Bápuji 1st
Raoji Narayen
Balwant Govind
Mukand Dinkar
Bhao Govind
Ganesh Bapuji 2nd
Monaji Abu
Govind Gopál
Balwant Rajaram
J. V. D'Souza
Sayana Saibu

Revenue Survey

H. D. E. Forbes, Esqr.

Sub-Surveyor.

Kubar Parbhudás
Jugal Mánsukhrám
Pachhu Kisor

(6.) The area finally surveyed comprises sheet 31 and a quarter of 32; also 78 and 79 with a small portion (56 square miles) of sheet 10a of Kattywar. This small portion was surveyed by us on the 4-inch scale as it was British Khálsa land which I thought desirable to have mapped on the same scale as the rest of the territory to which it pertained and adjoined.

(7.) The orders of Government restricting the scale to 2 inches to a mile were received too late to admit of any alteration in the field arrangements, but although the British Khálsa land was surveyed on the 4-inch scale it will all be mapped on the 2-inch scale; so that the cost will not be appreciably more than if it had been surveyed on the 2-inch scale. The field sections have been reduced to half scale in the Government Photozincographic Office here and from the reduced copies fair maps are traced.

(8.) The area topographed is, as will be seen on referring to the accompanying Index map, in two parts, which I may call the northern and southern. The northern portion includes a large part of the Viramgam taluka and a small part of the Sánand taluka of the Ahmedabad collectorate, a part of the Kari Mahal, and six villages of the Pátan Mahal of the Gaekwar's territory, and a small part of the Mahikánta. The Viramgám taluka has now been completely surveyed with the exception of 4 detached villages situated in sheets 72 and 77, and the Sánand taluka is also complete with the exception of 8 villages in sheet 7. In this northern area are the following principal towns:—

Viramgám—a taluka town; population about 20,000, with its municipality, a Mamlatdar's court, and a Railway station where the line from Khárághora (distance 14 miles), the great Government Salt station, joins the Wadhwán and Ahmedabad line.

Mándal—an important Khálsa town, with a population of about 7,000, and having a municipality and a Post office.

Detroj—a Khálsa town, with a population of about 3,000, and a branch Post office.

Kari—the chief town of the Kari Mahal, Gaekwar's territory, which has a somewhat interesting history attaching to it. It has a population of about 17,000, and a fine palace, and is fortified by a good wall from which it is styled *Kila* Kari. It is the residence of a Wahiwatdar (Manager), a Mamlatdar, and a Foujdar, and has a Post office. In 1802 it stood a siege and was taken by Sir William Clarke on the 30th April of that year from Malharao Gaekwar, who, a Jaghirdar of Kari, was nominally a dependant of the Gaekwar of Baroda to whom an annual tribute of Rupees 120,000 was payable, and who though within the Gaekwar's territories was as independent of him as the latter was of the Peishwa. Malharao rebelled against him, and perhaps but for the British troops might have maintained his independence, but on the capture of Kari he was taken prisoner, and Kari and its district were made over to the Baroda Gaekwar, who in consideration of the British services ceded the Chikhli pargana, now a taluka of the Surat collectorate, to the British Government. Malharao's father was the first Prince of Kari; he was established there by *his* father Pilaji Gaekwar in 1731. The palace and town walls were therefore probably built soon after that date.

Bechráji Mátha—a village in the Pátan Mahal, Gaekwar's territory, of only 123 inhabitants, situated near the village of Bechar of 620 inhabitants, famous for its temple and its melas (fairs). A mela is held there every month, but once a year in the end of September there is a famous and very largely attended mela visited by Hindus of all castes from all parts of Guzerat.

Katosan—a Thákur's town under the Mahikánta Political agency. It has a population of over 2000, and has a number of dependent villages. There are other villages of over 1000 inhabitants but of no particular importance.

(9.) The whole of the northern area is without any through drainage. There is an abundance of tanks which appear to accommodate the whole of the rainfall. There is not a single watercourse which flows either into the Runn of Cutch on the west, or into the Sábarmati river on the east. A few watercourses, without even sufficient importance to carry a name, drain into tanks or lose themselves in the flat country. There is a large lake on the north-west margin called Wanod-na-Saran (from Wanod, a neighbouring taluka town under the Kattywar Political agency) which covers when it is full about 6½ square miles. Half of this falls within our margin, the other half has been surveyed by the Kattywar Party.

(10.) The country on the east of the northern area is finely wooded with Mango, Kirni, Tamarind, Banian, Pipal, Nim, Wood Apple and other trees, and undulating to an extent embarrassing to the plane tabler, as the undulations conform to no marked system of drainage, but are very irregular; so that had the country been accurately contoured, the contours would meander so as to defy eye sketching, that is to say, no two surveyors would have represented the same ground in the same way without spending a very long time over it. The west of this area is very flat and open, the trees being almost confined to the immediate vicinity of the villages. The soil also is very different on the east and west. On the west it is clay with scarcely any admixture of sand, while on the east the sand predominates, so that within a distance of 30 miles the general aspect and character of the country undergoes a very marked change

(11.) The Bombay Baroda and Central India Railway traverses the northern area from west to east not far from its southern margin, and the Ahmedabad and Viramgám road enters the southern margin at 6½ miles from the south-east corner of sheet 79, but this road is of no importance now as an engineering work; part of it, between Sánand and Viramgám, has been taken up for the permanent way of the Railway, and the rest is sadly out of repair; east of Sánand in sheets 80 and 8 the road is in good order. The Government telegraph wire just crosses the north-east corner of this area, and about 6 miles of its length lie within the margin. There are no other engineering works in the northern area.

(12.) In this part of the country crime abounds to an alarming extent. Freebooters take advantage of the many political divisions of the country and evade the Police of one state by retreating into another. When I was at Kari a troop of the Gaekwar's cavalry halted there for a few days in the course of their search after some of these robbers. Fortunately the robbers think it politic not to molest servants of the British Government, and so none of our Surveyors were interfered with.

(13.) The southern area comprising sheet 31 and the north-west quarter of sheet 32, includes part of the Broach, Ámod and Ankleswar talukas of the Broach collectorate (which is now with the exception of a small portion of the Ankleswar taluka and a very small portion of the Ámod taluka completely surveyed), part of the Sinor Mahal of the Gaekwar's territory, also part of the Rájpipla territory and of the Sánkhera Mewas under the Rewákánta Political agency.

(14.) In the southern area are the following principal towns:—

Broach City and Civil station—with a population of about 37,000. This is apparently a city of great antiquity and said to have been known to the ancient Chinese under the name of Polee-kie-tch'e-po', the capital of a kingdom on the Nai-mo-tho or Nerbudda.* Arrian the Greek, and Ptolemy the Egyptian historian of the Augustan period, speak of it as Barigaza situated on the Narmadas; and the unknown author of the Periplus of the Erythrean Sea, geographically identifies it with Barigaza by the statement of its being "30 miles on the Narmadas" and by his accurate description of the "bore" or tidal wave of the Gulf of Cambay. Its name has at various times been much transformed from the original Brigukacha, literally the delta of Brigu the tutelary saint of the river whose shrine is still to be seen in old Broach. "To the Arabian travellers of the tenth and twelfth centuries it was known at different times "as Baroh, Baros, and Bahruj; the latter phonetically the same as it is now in Guzerati. It has had "at least a dozen forms in English in three generations: but Broitsh, Borich and Broach seem to be the "last." The administration of Broach and its dependent territory changed hands several times in the 18th century. It was taken in 1772 by the British who entrusted it to a Native Chief and council till 1783, when it was conferred on Máhádáji Scindia on account of his valuable aid and services in 1779; but in 1803 Scindia took up arms against the British, and in that year Broach was taken by storm and subsequently ceded by treaty to the British in whose hands it has remained ever since. Broach is now famous as a great cotton centre, and boasts of several spinning and ginning mills and presses. The town is on the Nerbudda and covers an area of about 2 miles by nearly ½ a mile. The Civil station is at the west

* From para. 10 of Mr Beyt's Report of the Revenue Settlement of the Broach Taluka, No. 1025, dated 20th October 1871. Published by Government of Bombay.

end of the town, the Railway station at the east end. It has a municipality and the usual offices to be found at every administrative centre of a district.

Ankleswar—the chief town of the taluka of that name, has a population of nearly 9,500, a Mamlatdar's court, a municipality, a Post office, and a Railway station which is nearly due south of Broach station at a distance of 6 miles. It is on the south side of the Nerbudda and about 3 miles from its present bank, but on the edge of what is the traditional old bank. The river must have changed its course very many years ago as there are several very populous towns on the lower ground between the ancient and modern banks. Ankleswar was ceded to the British by the treaty of Bassein in 1802.

Sinor—the chief town of the Gaekwari pargana of that name, has a population of nearly 6,000. Like every such town it has its Wahiwatdar, Mamlatdar, and Foujdar. It is situated on the right bank of the Nerbudda. The bank is here very precipitous and varying from 90 to 120 feet; the communication therefore between the town and the water is effected by wide ghats of masonry steps. It has also some fine entrance gateways.

Tankári—a large town of some 3,200 inhabitants; on the main track of communication between Broach and Baroda, has its traveller's bungalow, and is about 13 miles from Broach.

Sukal-tirth—population 2,900; *Janor*—population 2,600; and *Nikora*—population 2400: are three towns in the Broach taluka on the right bank of the Nerbudda, the first two are about 67 miles apart and the last intermediate between them. Sukal-tirth is about 15 miles from Broach, and is famous in having its name always connected with a notable Banian tree under which it is said Alexander the Great encamped with his army*: Pliny mentions this tree as capable of affording shelter to an army of 30,000 men. On an island in the Nerbudda nearly opposite Sukal-tirth is now a dense wood in the place where this famous tree once stood it is said alone, and from its isolation was supposed by the natives to have sprung from the tooth-pick of Kabir, a Guru who grafted the tenets of several modern creeds upon a Hindu stock so craftily as to render the question of his disciples being Hindu or otherwise still open to debate. The island is called Kabiwar from its having a temple sacred to Kabir on it in the thick of the wood but no portion of it pertains to Sukal-tirth. It is divided between Nikora and Janor and two other intermediate villages Mangaleshwar and Augareshwar, and the wood is on the part which pertains to Mangaleshwar, but nevertheless this wood which from a little distance has so regular an outline as to appear like a single huge tree is always called the Sukal-tirth Banian tree.

Diva—population 2,000, and *Bhar Bhâta Bet*—population 2,000; these are two of the populous towns situated on the low ground between the ancient and modern banks of the Nerbudda mentioned in connection with the town of Ankleswar; they pertain to the Broach taluka.

Chandod—population about 3,000; on the right bank of the Nerbudda. It is a town under Mándwa in the Sánkhera Mewas under the Rewákánta Political agency. This town is on the eastern margin of sheet 31 and therefore serves well to define the extent to which the Nerbudda has been surveyed, it being mapped from Chandod to the gulf of Cambay.

Rund Bhálod—population 2,200; in the Rájpipla territory on the right bank of the Nerbudda. Rund is the old and Bhálod the new town, but both adjoin and make one large town the chief centre of a pargana and the residence of a Thanadar.

There are in this southern area 24 other towns and villages with populations ranging between 1,000 and 2,000. Among the still smaller villages is one Ratanpur remarkable for its cornelian. It is on the south of the Nerbudda in the Rájpipla territory. The cornelian is dug out of a hill near the village, and taken to Cambay where it is cut and polished chiefly by a number of blind folk, and sold to the public under the well known name of Cambay stones. Mr. Christie reported on these cornelian mines of Ratanpur in 1873 *vide* p. 34—a of Annual Report for 1872-73. There is also near Ratanpur, and within the precincts of a temple, a famous tree of ordeal, of which the trunk is cleft through and by it a man suspected of crime is made to assay to pass. His guilt or innocence is proved by the tree either contracting the opening and detaining the culprit, or by allowing him to pass through without hindrance; such is the popular superstition.

(15.) The southern area is traversed by the Nerbudda river which is tidal as far as the Gaekwari village of Ránápur about 24 miles in a direct line from Broach, but 36 miles by the river. Large native craft come up as far as the Railway bridge at Broach, but above that, craft up to 30 tons ply as far as Talakwara about 40 miles direct from Broach and 65 miles by the river. The Nerbudda has several small tributaries which flow into it from the Sátpura mountains: the western extremity of which enters the south of sheet 31; and the whole of the country between the Nerbudda and the Sátpuras is very much cut up with ravines and watercourses, making about 200 square miles of country extremely difficult to survey, particularly to hands who have been accustomed to the flat plains of British Guzerat. This part of the country is mostly very wild, thickly wooded in parts

* Vide para. 12 of Mr. Beyt's Report, No. 1025 of 20th October 1871.

with bastard teak and in parts with palm trees, and the soil is very stony. With the exception of the neighbourhood of the river, where there are many towns and villages, the interior of this part of the country is inhabited by Bhils, and the hills are the abode of tigers, panthers and other wild animals, which frequently allure the Broach sportsmen to pay them a visit. On one occasion Mr. Cusson was surveying a Nala when a tiger sprung out of a bush within 30 yards of him, on the other side of the Nala, and made off into the jungle.

(16.) With the exception of a small area of land in the vicinity of the Nerbudda called Bhâta and Gorat (both of these having a large admixture of sand in the composition of the soil) the remainder of the southern area is a great plain of black soil, which in the cold weather under the luxuriantly verdant crops presents the appearance of a sea of almost homogeneous brilliant green, beautiful to the eye of the Revenue Officer, but too monotonous to please an artist as it is not even broken by a hedge; the villages are scattered over it like islands from 3 to 6 miles apart, and a few babul trees stand out like beacons here and there.

(17.) The southern area includes 25 miles of the Bombay Baroda and Central India Railway, and the stations of Ankleswar, Broach, Chamárgám and Pálej. There are no metalled roads in this area (excepting those within Broach municipal limits) but there are several cleared roads which have the advantage of being straight, but can scarcely be called engineering works.

(18.) The Head Quarters of the party left Poona on the 8th November, and Office was opened at Broach on the 14th; but previous to leaving Poona each of the Surveyors was given his portion of work so that each went at once to his proper post. I distributed the party as follows. Triangulation and traversing in sheets 28, 29, 30, Lieutenant Gibbs and Mr. Forbes with three Native Surveyors of the Revenue Survey establishment. Topography of British Khálsa land in the northern area (sheets 78, 79) on the scale of 4 inches to a mile, Mr. D'Souza with 8 Native Surveyors including two new hands who had to be instructed in plane tabling. British Talukdari and Foreign territory in the same sheets on the scale of 2 inches to a mile, Messrs. Hickie, S. Norman and C. Norman. Topography of the southern area (sheet 31 and part of 32), Messrs. Christie and Cusson and Native Surveyors Gopal Vishnu and Bhao Govind. Drawing Office, Mr. McA'Fee, Mr. Ferns and 4 Native printers and draftsmen.

(19.) On account of the rapidity with which the plane tables on the 4-inch scale were completed in the previous season and the consequent difficulty in having boards always ready mounted and projected to take the place of boards completed, I before leaving Poona devised a means of mounting plane table sections on to the boards dry, which turned out successful in every way and enabled me to send new sections projected with graticule and data points to the surveyors by post or to give out two or three at a time to a surveyor who could take his completed section off his board and replace it with a new section in a few minutes; and so each surveyor had but one board which he never changed through the season.

(20.) The means I adopted were as follows; I fitted each plane table with a strip of deal on each of its four sides. Three screws clamped each strip to the board. The screws had flat broad heads but not broader than the thickness of the table, so that they never interfered with the play of the sight rule, and corresponding brass female screws were let flush into the sides of the table. I also adopted what is as far as I know a new method of mounting the paper on cloth. I lay the paper face down on an ordinary table, then wet and paste the cloth on the back; the overlaps of the cloth adhering to the table keep the paper and cloth perfectly tight during the process of drying. When dry the mounted sheet comes easily away from the table, and the sheet never having had its surface scrubbed with a sponge as in the ordinary process, presents a beautiful even appearance and is perfectly flat; such a sheet can readily be stretched on a plane table and secured with the deal strips and brass screws if holes are cut in it to admit the screws and made sufficiently large to admit of a little play up and down. If once made tight in the cool of an early morning it never requires further stretching.

(21.) After remaining 3 days at Broach, I began moving about sheet 31 among the plane tablers, and remained there till the 23rd of December when I went to the northern area and moved about among the plane tablers there until the 22nd of February: I then returned to Broach and in a few days called in Lieutenant Gibbs to relieve me of the charge of the Party to enable me to avail myself of three months' privilege leave which I took from the 13th of that month. I also called in Mr. Forbes and his Native Surveyors who had by that time completed a sufficiency of traversing in sheets 28 and 29 for our next season's requirements, and with the assistance of Mr. Forbes and one Native Surveyor I commenced the compilation of a map of Broach on the scale of 16 inches to a mile from the sheets of the city survey drawn on the scale of 66 feet to an inch by the Revenue Survey. This was a work requiring careful management as 71 separate maps had to be fitted together and correctly placed as to the graticule. Mr. Forbes's other two surveyors commenced the transference of fiscal details from the Revenue Survey village maps to the plane table section that had already been completed.

(22.) On my return from privilege leave on the 7th June, Lieutenant Gibbs handed me a most satisfactory memorandum giving full particulars of his management of the Party during my absence. Leaving the drawing office under Mr. McA'Fee in Broach where also he left Mr. Forbes and his Native Surveyors, he spent the remainder of the season in the southern area inspecting the different surveyor's work; and he also supplied a few points by triangulation where there was a deficiency. As the delineation of the hills in sheet 31 was *something* quite new to the surveyors working in that sheet, and as Lieutenant Gibbs could *not* possibly have found time to initiate them himself in the art of hill sketching, he wisely sent for Mr. D'Souza *from* sheet 79 for this purpose, and directed Mr. Hickie and Mr. C. Norman to supervise the Native Surveyors who had been working under Mr. D'Souza. On the 3rd May he rejoined the drawing office *which had opened* work in Poona on the 1st.

Lieutenant Gibbs.

(23.) I now state *seriatim* the work performed by each of my assistants. To Lieutenant Gibbs was entrusted the preparation by triangulation and traversing of the foreign territory in sheets 28, 29, 30 for final survey. Where he found it practicable—that is where the country was fairly open—he spread a net-work of triangles, but through the woody parts he ran a system of traverses at regular distances apart based upon the triangulation. The stations on the west flank of the Singi Meridional Series, the east flank of the Mahi Series and the net-work of sheet 31 afforded the requisite points of departure and closing for both his triangulation and traversing. He was assisted in the traversing by Gopal Vishnu, Ganesh Bápuji 1st and Ganesh Bápuji 2nd, but each of these was employed on work elsewhere during part of the season.

Mr. Forbes.

(24.) Mr. Forbes assisted by his three Native Surveyors of the Revenue Survey Department had the preparation by traversing of the British territory in sheets 28 and 29. The river Mahi may be said to be the boundary of the British territory though there are small divergences therefrom. The traversing of the British territory cannot be laid out in any regular line but has to strike upon all the tri-junctions of village boundaries as well as on each village site, for reasons which have been explained in former reports.

Mr. D'Souza.

(25.) Mr. D'Souza had the supervision of the plane table surveying on the 4-inch scale of the British territory in the northern area. I placed under him Lakshmán Gharpuri, Mukand Dinkar, Ganesh Bápuji 1st, Raoji Narayen, Govind Gopál and Balwant Rajaram; and his duty was to keep moving about among these six men inspecting their work and seeing that they made proper use of the Revenue Survey village *maps*. He also had under him two new hands who had to be taught, Sayana Saibu and another who turned out a failure and had to be discharged. Subsequently I had to withdraw for the drawing office Lakshumán Gharpuri and Mukand Dinkar—Sayana Saibu having meantime been taught—and later on Ganesh Bápuji 1st to help Lieutenant Gibbs with the traversing. Mr. D'Souza had to be continually on the move, and although it was not necessary for him to take up a plane table himself his work was hard enough. Towards the close of the season as stated in para. 22 he had to proceed to the southern area as an instructor in hill drawing.

Mr. Christie.

(26.) Mr. Christie was employed plane tabling in sheet 31, both British territory on the 4-inch scale and foreign on the 2-inch scale, until the middle of March when he relieved Lieutenant Gibbs in charge of the work of triangulating and traversing the foreign territory in sheets 29 and 30. His out-turn must be considered very good.

Mr. McA'Fee.

(27.) Mr. McA'Fee was employed the whole season in the drawing office; his duties were multifarious, generally supervising the drawing work and projecting the data on the plane table sections.

Mr. Hickie.

(28.) Mr. Hickie turned out 210 square miles (including overlaps) of plane tabling in the most difficult part of the northern area. Being wholly foreign territory it was all on the 2-inch scale; it is superficially the largest area surveyed by one person in the season, and keeping in view the nature of the ground, must be considered very good.

Mr. Cusson.

(29.) Mr. Cusson was employed at first on British territory on the 4-inch scale in sheet 31 and then on the foreign territory on the 2-inch scale in the same sheet. Subsequently I transferred him to other ground and then directed him to take up British territory on the 4-inch scale in sheet 32.

Mr. S. Norman.

(30.) Mr. S. Norman was at first employed in the northern area where he completed 82 square miles of plane tabling on the 2-inch scale; this he had just completed when I was compelled to transfer Mr. Cusson from Baroda to British territory, and I therefore directed Mr. S. Norman to take up the work in Baroda territory in the southern area that Mr. Cusson had to abandon, and during the remainder of the season he worked in the southern area. From the instruction he received from Mr. D'Souza and subsequent practice in the Rajpipla hills he became a very fair hill sketcher. His out-turn must be considered very good.

Mr. C. Norman.

(31.) Mr. C. Norman was employed exclusively in the northern area plane tabling on the 2-inch scale. He is an accurate and careful surveyor, but his out-turn is not so large as his brother's on account of his falling sick and being incapacitated for work in the open from the 1st of April, and also from his having to survey the city of Kari the traversing of the main thoroughfares of which detained him a week. During the latter part of the season, Lieutenant Gibbs employed him in the drawing office at Broach.

Native Surveyors.

(32.) Of the Native Surveyors, Gopal Vishnu and Ganesh Bápuji Lelé proved themselves useful hands both with the plane table and at traversing, but the latter is not so active as the former. Raoji Narayen and Bhao Govind have the best out-turns of plane tabling: the latter was sick for a month and had a very intricate piece of ground in one plane table, so that his out-turn is less than that of the former.

The Drawing Office.

(33.) During the field season the eastern half of degree sheet II was commenced and completed, and as it contains 4 sheets of the most thickly populated part of Guzerat as well as the most thickly wooded, the drawing and printing of this map was no light task. Mr. Ferns drew and printed the whole of it. Mr. Ferns had also to re-draw half a section of sheet 80 on the 4-inch scale which had been injured. The printing of 10½ sections on the 4-inch scale was commenced and completed, and that of 7 sections had been commenced in the previous recess but was completed in the field—altogether equivalent to about 14 sections. The drawing office was weakened by my employing two hands, Lakshmán Gharpuri and Mukand Dinkar in plane tabling, while two new hands were being instructed in that branch so as to utilize the services of the khalassies who would otherwise have been idle; and owing to the inability of these new hands to learn plane tabling quickly, the two Native Surveyors were absent from their posts in the drawing office till the latter end of January. From this cause and from the occupation of Mr. Ferns on degree sheet II, seven sections on the 4-inch scale remained incomplete when the office returned to Poona.

(34.) The orders of Government restricting the scale of British territory to 2 inches to the mile in place of 4 inches to the mile has somewhat burdened us with another innovation inasmuch as it entails a new style of draftsmanship, and so the preparation of these maps for reproduction on that scale has somewhat thrown our mapping into arrears, but I have made the drawing office stronger than last field season and I hope to finish off all the mapping before the Party returns again to recess quarters.

(35.) The maps published on the 2-inch scale will contain all the detail of the 4-inch scale with the exception of the fields and their numbers which were derived from the Revenue Survey maps; and that kind of detail will by no means be entirely dispensed with, as the trijunctions of fields, along the village boundaries, along the boundaries of waste land and wherever the plane table stations occur, have still to be inserted with a sufficiency of their numbers printed to enable identification of the field corners. But the drawing of these 2-inch scale maps is very much finer than that of those on the 4-inch scale and this increase in fineness of execution means increase in time of execution, so that the time we save in detail we nearly lose in superior workmanship. The maps now in course of preparation are—as works of art—superior to anything we have hitherto succeeded in producing, and I doubt not will be greatly admired by all who have to use them.

(36.) The computations of the triangulation and traversing of the past season are all approaching completion, and will be completed before we again take the field.

TABULAR STATEMENT OF WORK EXECUTED BY THE GUZERAT PARTY, DURING THE FIELD SEASON 1875-76.

Details of Triangulation.

Observer's Name.	Instrument.	Area triangulated and traversed in square miles.	No. of stations visited.	3 Angles Observed				2 Angles Observed.				Average No. of trigonometrical and traverse points per square mile.	Average No. of heights per square mile.	Remarks.
				No. of triangles.	Triangular error.	Error per mile.	No. of heights.	No. of Intersected points.	No. of triangles.	Error per mile.	No. of heights.			
					"	inches.				Feet.				
Lieut. J. E. Gibbs, R.E.,	6-inch by Cook and Sons [a]	1650	22	13[c]	17·2	...	15	50	71	0·9	7	Exclusive of traverse intersected points, 1·8	Including 107 trigl. heights, the existing levels of the B. B. and C. I. Railway, and the coming season's work of the Leveling party, there will be an ample number.	[a] 10-inch by Troughton & Simms used at few stations in the base-line work. [b] of base-lines. * [c] The third angle of one of these was observed by Mr. Christie. [d] Mean of 15 common values. [e] 17 of these stations were fixed by interpolation, 2 by two angles of a triangle, and 3 were old stations.
			9[b]	3	19·2	...	5	19	29		7			
Do. do.	Colonel DeLisle's 8-inch		7	5	11·5	4.2	2	16	22	...	1			
			29	34	18·5	6·1	24	88	169	1·8[d]	0			
Mr. A. Christie,	6-inch by Troughton and Simms		22[e]	40	...	6·8	19	18	33	2·3	0			

Details of Topography.

No.	Name.	Area surveyed in square miles: 4-inch scale.	2-inch scale.	Total.	No. of plane table stations per square mile.	Remarks.
1	Mr. A. Christie, ...	68·27	69·01	137·28	9·3	Mr. A. D'Souza was engaged in the general supervision and examination of the work of the Native Plane tablers, and also in the instruction of Mr. S. Norman and Bhao Govind in hill sketching. *a* employed during part of the field season in the office. *b* One month sick.
2	„ J. Hickie, ...	...	235·85	235·85	11·6	
3	„ G. D. Cuzzon, ...	128·34	76·34	204·68	8·1	
4	„ S. Norman, ...	...	210·65	210·65	8·8	
5	„ C. Norman, *a*	...	143·50	143·50	11·0	
	Native Surveyor.					
1	Gopal Vishnu, ...	79·57	...	79·57	14·4	
2	Lakshuman Gharpuri, *a*	51·99	...	51·99	11·6	
3	Ganesh Bápuji Lele, ...	44·16	...	44·16	13·9	
4	Raoji Narayen, ...	92·78	112·51	205·29	9·4	
5	Balwant Govind, *a* ...	37·43	...	37·43	15·3	
6	Mukand Dinkar, *a* ...	45·13	...	45·13	10·4	
7	Bhao Govind, *b*	23·65	100·52	124·17	16·3	
8	Govind Gopál, ...	104·91	...	104·91	11·5	
9	Balwant Rájarám, ...	120·80	...	120·80	12·2	
10	Sayana Saibu, ...	72·84	...	72·84	16·7	
11	Vital Vishnu, Khalási ...	53·61	...	53·61	16·1	
	Total and Averages, ...	923·48	948·38	1871·86	11·3	Exclusive of overlap.

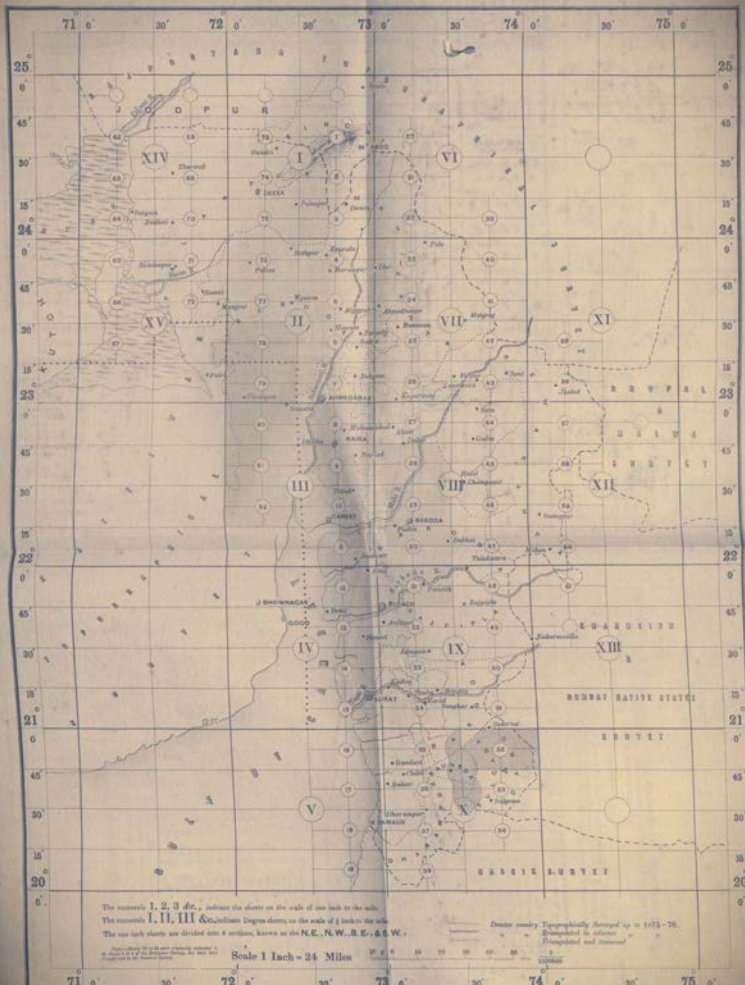
Details of Traversing.

No.	Name.	Instrument.	Linear miles of traversing.	No. of stations.	Average error per 1000 links.	Average angular error per station.	Remarks.
						"	
1	Lieut. J. E. Gibbs, R.E. ...	6-inch Theodolites by Cook and Sons.	73·802[a]	147	0·78	20·7	[a] Main traverses, which have been computed in "systems", so as to harmonize, two traverses by Gopál Vishnu having been included in the "systems". [b] Boundary traverses. [c] from 6 traverses. [d] from 12 traverses. A sufficiency of the rest have not been computed in order to obtain averages.
2	Mr. A. Christie, ...		4·137[a]	5			
3	Gopal Vishnu, ...		74·204 / 91·501[b]	367	0·94[c]	30·2	
4	Ganesh Bápuji Lele, ...		150·226 / 14·813[b]	292	1·13[d]	15·0	
5	Ganesh Bápuji Mándre, ...		224·800 / 131·650[b]	944			
6	Lieut. Gibbs (base-lines)*		8·535				
	Revenue Survey.						
1	H. D. E. Forbes, esq. ...		43·253	180			
2	Kubar Parbhudáss, ...		105·753	309			
3	Jugal Mánsukhrám, ...		125·310	393			
4	Parbhu Kisor, ...		83·412 / 27·374[b]	280			
			893·432 / 265·338[b]	2917			
	Total, ...		1158·770				

* Note.—Three base-lines, each making a triangle with a station of the principal series, were chained, for the purpose of starting and closing traverses. The angles of these triangles were observed with as much care as if they had pertained to ordinary triangulation.

GREAT TRIGONOMETRICAL SURVEY OF INDIA

INDEX CHART OF THE GUZERAT TOPOGRAPHICAL SURVEY


71 0′ 30′ 72 0′ 30′ 73 0′ 30′ 74 0′ 30′ 75 0′
25 24 23 22 21 20
I II III IV V VI VII VIII IX X XI XII XIII XIV XV
BOMBAY NATIVE STATES
BARODA TERRITORY
The numerals 1, 2, 3 &c., indicate the sheets on the scale of one inch to the mile.
The numerals I, II, III &c., indicate Degree sheets, on the scale of ½ inch to the mile
The one inch sheets are divided into 4 sections, known as the N.E., N.W., S.E., & S.W.
Scale 1 Inch = 24 Miles
Denotes country Topographically Surveyed up to 1875–76.
" " Triangulated in advance " " "
" " Triangulated and traversed

Photolithographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Dun November 1876.

XII. Extract from the Narrative Report—dated 12th December 1876—of Major J. HERSCHEL, R.E., F.R.S., Deputy Superintendent 2nd Grade, in charge of Calculating and Printing Branches of the Computing Office.

(1.) I received charge of the office on the 21st March last from Mr. W. H. Cole, M.A., whose report, printed in the Appendix to the Superintendent's Annual Report for 1874-75, reviewed the operations of this Office, as well as those of the Drawing, Photozincographic, and Printing Offices, for the previous 17 months, from May 1874 to September 1875 inclusive.

(2.) With regard to the work done during the interval prior to Mr. Cole's departure on furlough, I have to rely on the monthly reports: including that the present account covers the 13 months from October 1875 to October 1876.

(3.) Mr. Cole's departure was somewhat sudden, and as it was followed a fortnight later by that of Colonel Walker, the charge would have proved a very onerous one had the superintendence of all the above branches devolved upon me without preparation. Colonel Walker was therefore pleased to separate the Drawing and Photozincographic Offices and to place these under Captain Thuillier, R.E., who was to officiate for him as Superintendent; leaving the Computing and Printing Offices to my care.

(4.) Within a few days of my accession to office the preparation of the usual monthly report directed my attention to a system of diary keeping which had been commenced under orders from the Superintendent about 15 months before, the object of which, as I understood it, was to obtain the actual cost of any individual piece of work, as in a factory. I could not learn that this result had ever been obtained, although the time of each workman was duly accounted for. In endeavouring to carry out what appeared to be the intention, it became evident that in the absence of any indication what special work was to be the subject of particular estimate, a very elaborate specification of details was necessary. This presented a serious difficulty, to provide for which would require a closer supervision than I could give. The only practical escape seemed to be to obtain—at any rate at first—the relative cost of classes of work. I accordingly classified as soon as I could do so, and very soon obtained what seemed a satisfactory result, which I introduce here as a guide to the order which will be observed in this report. It is necessary however to remark that, as there is an annual periodicity about some kinds of work, is would be premature to draw very close inferences from so partial a piece of statistics, which is in fact on trial. On the other hand there is reason to hope that, as each individual concerned can see in the monthly statements (of which the table shows only sum totals) the actual cost in rupees of his share of the several kinds of work on which he has been occupied, there may grow into existence, with proper help, a sort of restraining judgment as to the worth of it.

Tubular Statement of Cost in Rupees of different Classes of Work done in the Computing Office.

	Classes	July.	August.	September.	October.	November.	December.	Average per cent.
1	Records ...	10	5	5	17	12	23	½
2	Computations ...	662	391	506	463	439	514	22
3	Accounts ...	47	45	33	37	43	37	2
4	Returns ...	62	298	74	118	69	78	5
5	Supply ...	46	88	131	104	107	68	4
6	Press copy ...	626	657	786	633	434	323	25
7	Press proofs ...	377	220	225	304	348	263	13
8	Charts ...	184	122	31	21	159	129	5
9	Meteorology ...	34	35	46	52	74	14	2
10	Library ...	18	9	8	8	7	1	½
11	Correspondence ...	94	56	54	60	39	17	3
12	Stations ...	33	37	65	37	178	58	3
13	Leave ...	58	162	181	210	70	74	6
14	Holiday ...		71	58	88	76	484	6
0	Miscellaneous ...	116	171	164	95	72	44	3
	Totals ...	2367	2367	2367	2247	2127	2127	100

It will readily be understood that the designations of classes here given are often mere catchwords

* The figures for November and December have been added from later reports by desire of the Superintendent.

denoting a variety of items.

I now proceed to take the above classes in order and will use the opportunity to indicate in some detail what they represent.

(5.) *Records.* In no department of the public service probably are records more valuable than in that of Survey. They represent money sunk or funded as the case may be, and the strictest precautions have always been taken to guard against loss or destruction. The best safeguard no doubt is prompt publication, but this is not always possible. Our progress in this direction is however undoubtedly making a large mass of MS records rank chiefly as mementos of those who wrought them. Our museum of these is maintained and must continue to be maintained so long as field records continue to be annually or from time to time received. Part of the work under this head relates to the examination, indexing, paging, cataloguing, &c., of these later additions. The gradual accretion of MSS since the present accommodation was allotted has become a source of some difficulty and anxiety; and the Record Room and Library alike demand study to prevent their becoming crowded.

(6.) *Computations.* It appears desirable to restrict this class as much as possible, and further to subdivide it, with a view to facilitate the desired appraisement of different kinds of work. Having regard to the natural current of operations it is not difficult to see what the various subclasses should be. The following have been laid down as guides for the computers in preparing their several monthly accounts of work. *Subclass* (a) claims all computations directly connected with *named* series: *subclass* (b) comprises levelling and tidal reduction: *subclass* (c) astronomical and pendulum work: *subclass* (d) is devoted to the reductions of associated series, and referring to the timehonoured plan of this Survey, may fitly be known as the gridiron subclass. I must pass over (a) for the moment. In (b) I am not aware of anything requiring specific mention having been done during the twelvemonth. In (c) a good deal of work was done in the early part of the year in the course of preparing the pendulum operations for press, but I am not in a position to describe it precisely. In specifying the work under (d) it will be necessary for me to go more into detail.

(7.) Three large areas of triangulation, which have been frequently mentioned in these reports under the names of North-West Quadrilateral or N.W.Q., South-East Quadrilateral or S.E.Q., and North-East Quadrilateral or N.E.Q., have to be considered. Of these the first deals with 8 series, the second with 6, and the third with 15. Thus the three Quadrilaterals incorporate 29 distinct series of triangles, each of which owns a name and a set of records and of computations. They form as it were three quarterings of the great Indian Survey shield. The fourth quarter—the South-West Quadrilateral or S.W.Q.—need only be mentioned: we have not anything to do with it here. It will eventually consolidate 5 or 6 other series with those already mentioned.

(8.) There is little to be said here about the N.W.Q., which has already been frequently described, further than that the reduction of it embodied most of the experience which has guided us in subsequent operations of that nature. Nor is it necessary in the present connection to say much of the S.E.Q., the reduction of which was reported last year as nearly complete. The work which followed thereupon will find its place in another page. Of the N.E.Q. reduction also it would be easier to say little than much; but as this is a report I must briefly describe its features.

(9.) It was originally intended to restrict this job to those old series running north and south, between the meridians of Delhi and Calcutta, which together with a chain of triangles skirting the Himalayas and another along the parallel of Calcutta (or nearly so) gave, no doubt, the first quaint suggestion of a gridiron. These series have always had rather a bad reputation as compared with the nobler ones of more recent days, and in designing the programme of successive reductions they were assigned a third place so that they might rest upon, instead of offering a weak support to, their stronger neighbours. This was well; but to the eastward of these again lay 4 connected series which, being of the higher order of merit, would in this way run a chance of being unfairly dealt with. These were therefore included in the N.E.Q. scheme; which, in its extended character, presents 49 equations of condition.

(10.) There is one peculiarity about this third gridiron reduction which requires special notice. The first and second are independent bodies of triangulation, having nothing in common except at the corner where they meet: but as at this corner they have one side of one triangle in common, upon which each may be considered as based, the two rigid wholes become in effect one rigid whole. In the vacant areas forming the other two quarters the triangulation occupying them has to be adjusted. Thus the N.E.Q. may be considered as a piece of triangulation which has to conform to a much larger number of fixed points. The same will be the case in the fourth quarter. This in no way adds to the difficulty; on the contrary the immediate effect is to remove two equations, one of which would link together many of the others in such a way as to increase the trouble of solution of the ultimate normal equations. This last operation forms however so small a portion of the total labour that it would be a mistake to lay much stress upon

it. The great mass of the work is to be found in the formation of the coefficients, and every coefficient saved represents there an economy which far outweighs what would result from its mere absence in the final equations. If I am not mistaken 90 coefficients out of 641 are thus saved, as a direct consequence of the N.E.Q. being based upon the already completed N.W.Q. and S.E.Q.

(11.) In the annexed table I have endeavoured to present some statistics of the three quadrilateral reductions. The last two lines require a word of explanation. The more entangled a set of given conditions are *inter se* the more do they react the one upon the other. Every such reaction gives rise to a term (with its coefficient) in the ultimate equations between the indeterminate factors—also called above, and in the table, normal equations. The average number of terms in these equations is therefore, roughly, a measure of the entanglement, or as we may say, of the interdependence of parts. Again, as the parts so dependent on each other consist in every case of a number of triangles, and therefore of angles, the average proportion of the latter is some measure—probably a very rude one,—of the weakness, as the other is of the strength, of the framework considered as a whole. The inference is not entitled to much weight, but it has some small interest.

GRIDIRON FUNCTION TABLE.

	N.W.Q.	S.E.Q.	N.E.Q.
Number of Associated Series	8	6	15
„ Circuits	5	3	12
„ Circuit triangles	549	277	573
„ Non-circuit triangles	268	169	120
„ Equations of Condition	23	15	49
„ Normal Equation Coefficients	329	165	551
„ Products forming the same	40,050	16,664	50,962
„ „ „ neglecting sub-diagonals ...	23,204	9,784	29,132
Average terms per normal equation	14	11	11
„ angles concerned per term	183	151	139

(12.) A large part of the preliminary calculations for the N.E.Q. had been prepared prior to Mr. Cole's departure. The eastern series were the least advanced, as their inclusion had not been decided upon. I was enabled however to push on with the calculation of coefficients, and afterwards with the solution of the equations, of the ten western circuits. The elimination has been carried as far as the 38th equation, where it has been stopped for the present. Every equation as formed, and every elimination as completed, has been subjected to some test. For one or two of these I am indebted to Baboo Cally Mohun, who is very expert in devising these checks. That I may not be understood to imply that the introduction of checks was at all a novelty I should explain that the great increase in the number of equations rendered it impossible to adopt the arrangements of the N.W.Q. and S.E.Q; and that in devising others more suitable to the altered circumstances, different facilities presented themselves for securing checks. These were of course taken advantage of.

(13.) Having been instructed to curtail calculation as much as possible—in view of the inferior character of the triangulation—I have given my closest attention to this point. It is often a matter of extreme difficulty to judge rightly what measure of accuracy is sufficient at each stage of a series of numerical operations, in order to secure a satisfactory conclusion. On the one hand, too much caution may entail fruitless labour; on the other, too much hardihood may lead to failure. Perhaps I have erred on the latter side. Should the event prove this, I shall be the less excusable through having had two previous sets of computation by which to be guided. At the same time there is an unavoidably greater risk of sensible error in what mathematicians call a first approximation, where the quantities to be found are (as in the N.E.Q.) comparatively large.

(14.) We may now return to subclass (a) of art. 6, which includes all computations directly connected with named series. The extension of the N.E.Q. to include the Assam, the East Calcutta, the Brahmaputra, and the Eastern Frontier necessitated the revision of the original computations of these series, portions of which, though the observations were taken with good instruments by good observers, had become in some sort obsolete through the introduction of better elements of origin and more refined methods of preliminary treatment. They were in part recomputed, and the results were adopted in obtaining the errors to be dispersed by the N.E.Q. Reduction.

(15.) A large amount of secondary triangulation belonging to the several series forming the S.E.Q. has been corrected, revised, or where necessary recalculated, upon the basis of the finally corrected principal elements of that section.

(16.) The height deductions along several of the meridional series of the N.E.Q. have been gone over, in anticipation of their actual requirement for publication along with the other results on those series, in order to supply the best available materials in Oudh, Rohilkhand, and N.W. Provinces, for the level sheets in course of compilation.

(17.) For the preparation of level charts the Drawing Office has acquired from various sources *data* some portion of which is scarcely inferior to that supplied by the G.T.S. levelling, and is connected with it and with occasional tower stations of the series which traverse the N.W. Provinces, Oudh, and Bengal. The trigonometrical (or *signal* as distinguished from *staff*) levelling, obtained by vertical angles measured with the theodolite, though far less trustworthy than spirit (or staff) levelling is still good enough to be valuable when connected with the more reliable *data*. Accordingly it falls to this office to harmonize the two. The adjustment which is requisite in any such case may be effected either by a direct appeal to the method of least squares or by the application of a discretionary method of allotment. I was not aware that the former had ever been given a conclusive trial and therefore applied it in one or two of the cases which arose as above. I have since understood that the method has been tried, and discarded as being too refined for its purpose. Under these circumstances there is no occasion to say more about it than that if there should hereafter be any desire to repeat the experiment the form into which the work was thrown may perhaps be found of use. It is one which I think applicable to almost any simple problem of dispersion of error by least squares, however numerous either the equations or the unknown quantities might be.

(18.) It has been usual to reckon Astronomical Azimuths as among the operations of a series. They are so, no doubt, if we regard only the fact that they are almost invariably observed by trigonometrical parties conducting the usual field operations. But considered as computations, the necessary connection disappears. In classing these it seems best to assign them a place along with other geodetic measures. There are 42 astronomical azimuths at stations of the S.E.Q.: some of these have been computed now for the first time; others have been examined and where necessary corrected; and abstracts for press have been completed, or drafted. Of the above number 15 were observed subsequent to 1863, when a different method of registering level readings was introduced. The reduction of these last has received very careful attention, in the hope of ascertaining the requisite facial corrections as well as those due on account of error of verticality of of the azimuthal rotation axis. Owing however to the necessary ignorance of the state of the pivots at different periods there appears to be very little prospect of determining the former, and in that case it will be necessary to combine observations taken "face right" with corresponding ones taken "face left", the mean of which will be cleared of the facial errors. This amounts to much the same as measuring on 5 zeros with 10 microscopes, instead of on 10 with 5.

(19.) In connection with the subject of observed azimuths I may mention that an endeavour has been made to ascertain the general effect of the final reductions of the N.W.Q. and N.E.Q. triangulations upon the disagreement of geodetic and astronomic azimuths in those quarters. For this purpose Baboo Gunga Pershad has prepared, with great care, an abstract of *all* astronomical azimuths, showing in the case of those which admit of it, the final, and in all others the preliminary, disagreement. This is not the first time that a collection has been made, but as it has never before been possible to approach so closely to the facts, the abstract repays study. Of the 179 observed azimuths, the final reductions enable us so far to compare provisional discordances with final discordances in 85 cases. Of these 85, the azimuthal correction has in 62 cases the sign proper to reduce, and in 23 to increase the discordance. Of the 62 cases in which the sign is proper, the numerical magnitude is often too great, and sometimes (in 12 instances) sufficient to produce an increased discordance with changed sign. Thus, if we consider magnitude only, there are 50 decreases against 35 increases. That this is obviously the result which was intended when, by Colonel Walker's direction, the fundamental azimuth of origin of the Survey was changed—after an investigation very similar in some respects to this—by 1″·1, scarcely needs more than recognition: a general diminution of provisional discordances was a necessary consequence. The interest does not lie here, but in the further question, Apart from this constant correction, is there evidence of a diminution which may be fairly adduced as confirming the discipline to which the triangulation has been subjected? The answer is I think affirmative, but hardly positive. In some cases there is a marked appearance of correction; but, remembering that however perfect the triangulation might be, there would always remain the uncertain discordances caused by local attraction, this is inconclusive. Lastly there is some indication, in the outstanding preponderance of negative over positive discordances, that the change of fundamental azimuth was rather too small than too great.

(20.) The result on the whole is this. The absolute attraction at Kalianpur is almost conclusively proved to cause an azimuthal deviation of somewhat more than + 1″·1, and this quantity has been allowed for in determining the influence of local attraction at all the other stations yet reached by the final reductions. When the N.W.Q. and S.E.Q. are published, there will be available 85 determinations

of deviation, which have perhaps a better claim to rank as *absolute* than any yet given to the world. There remain 94 others to which the continued building up of the framework will extend a like character. Those in the extreme south, where the effect of lateral attraction on azimuthal azimuth ceases, must be looked for, in this connection, with exceptional interest. We may now return to the more prosaic subjects of this report.

(21.) *Accounts.* There is but little to be said about these. As a class it includes all time devoted to monthly pay bills and to the keeping of pay, contingent, and map accounts. These have been conducted by Mr. Wood, whose management of them has been satisfactory.

(22.) *Returns.* This class includes indents, estimates, monthly progress reports, stock and expenditure, and work of that character. It is of more importance and requires more experience, and when as in August the indents on England are under consideration the cost is exceptional. Some of the principal items are prepared by Mr. Wood. I annex a list.

Annual Report, materials for:
„ Estimate of Stores for Indent:
„ Indent on England:
List of Books and Periodicals required for the year:
Statement of Receipts and Issues of Stores for 5 years, and of Balances:
Review of Expenditure of Stores:
Monthly Progress Reports, in detail:
„ Statement of Cost of the Department:
Stationery and occasional Indents:
Stock and Expenditure Lists of printed Forms.

(23.) *Supply.* Under the head of supply I reckon the preparation of transcripts or abstracts from the professional records to meet the wants of field parties and other applicants; as also all work in connection with applications for information of whatsoever kind, by other offices. This is often a source of trouble, if not of actual waste of time, owing to the vagueness of the demand; but the steady increase of our publications enables us to meet a continually larger proportion year by year by the despatch of a Preliminary Chart, a Level Sheet, or a Synoptical Volume. Such supplies being matter of business only make but little show in the scale of cost, compared with their utility. During the past year, in addition to MS *data* supplied to about 20 officers, some 750 despatches of maps, charts, books, and forms have been made. Under this head should also be noticed—as directly connected with the extension of the supply of materials—the compilation of a revised list of maps and charts published at Head Quarters. This we hope to be able to print. Meanwhile a copy in MS has been supplied to the Surveyor General.

(24.) *Press Copy.* If we may judge from the monthly cost of this class, it stands first in importance. And when it is considered how very long and sometimes devious a chain of procedure is traceable from the early measurements of angle, through the preliminary calculations—revised perhaps as knowledge increased—up to the final stages by which the independent work of numberless hands has been welded into one consistent whole; it is not surprizing that it rarely happens that any single page of the original records can be put into the printer's hand. Not only this: the compilation of what is suitable for publication is something very different from selection and transcription. To the calculator it is very much what composition is to the writer, only that it must hang together by much more inelastic links. There may be no weakness, on his part—no mistakes, no oversights. Thus it is really the case that the preparation of press copy occupies a very large proportion of the computers' time. Where possible—and it very often is possible—the later stages of calculation are so conducted as to form this material. But a considerable part of what is to be printed *must* be compiled. Of this kind are alphabetical and other synopses of results, especially of secondary triangulation. Alphabetical arrangements are generally troublesome in proportion to their utility, and first drafts have commonly to be revised and rearranged before they are fit for the compositor. And then they must be compared with the original materials. Mere transcripts do not require this, but compilations take so much more time to check that it is unadvisable to reserve the comparison until the matter is in type. A great part of the expenditure under this head is to be accounted for by the necessity of revising part of the copy for the N.W. Himalayan Secondary Triangulation. It must have been a terribly tough job to prepare it at all—and I believe Mr. W. Todd is entitled to much of the credit of it—but when it came to be printed it hung on the compositor's hands too heavily and I directed what remained—some 200 pages of printed matter eventually—to be transcribed. There was also some revision of the orthography of native names at the same time. This was in Mr. Wood's hands at first but afterwards in Mr. Peychers'.

(25.) The synopses of secondary triangulation of the 6 series of the S.E.Q. (which likewise form press copy) have been continued and are now complete. Recomparison is required in one case. Press

copy is otherwise ready for the whole of the Synoptical Volumes of this Section, and these are in course of printing.

(26.) One other kind of press copy may be noticed here. A good deal of letter press now accompanies numerical charts, both those called "preliminary" and those devoted to levels. The printed matter is either put upon the chart before it is photographed, or accompanies it as a pamphlet. In either case the Computing Office is answerable for its being properly printed, and to a certain extent for what is printed. In the case of charts such as the level sheets, which are compiled in the Drawing Office, my responsibility was limited. The letter press accompanying 8 of these, prepared by Mr. Atkinson, has been printed in pamphlet form. Those which had been printed in earlier years, at intervals, were of different patterns, and I was a good deal perplexed which to adopt. Foreseeing a run of the same kind it seemed worth while to form a good pattern, as these typographical details are otherwise worrying. There is now a certain uniformity about these which I hope will prove satisfactory. The manner of printing upon preliminary charts has also varied a good deal, according to circumstances, from time to time; and I have endeavoured to incorporate the best parts in those which have passed through my hands; but there is still room for improvement, as my reluctance to make any changes has only been overcome with much hesitation. I beg to bring to notice the preliminary charts of the Rámnád and Eastern Frontier Series, 1874-75, the typography of which was arranged under my instructions by Mr. Wood.

(27.) *Press Proofs.* It will be hard to find anything interesting to say on this very dull subject. And yet so much harm, as well as annoyance, directly results from misprints—to say nothing of the merely æsthetic satisfaction in good printing—that it has a certain claim of its own. The subject stands third in order of cost; but as a great part of the reading, comparing, and correcting of proofs is done by the less highly paid members, it does in fact occupy a larger share of the time and labour of the office than can be done justice to here.. I therefore take occasion to express my full recognition of the results of careful training which has made it possible for printing of a really creditable order to be turned out almost wholly by Natives of this country. And in saying this I by no means underrate the critical supervision exercised by Mr. Peychers, on whose vigilance I have been able to rely more than I could have expected. Press proofs upon and accompanying preliminary charts have been dealt with almost entirely by Mr. Wood, who in this as in every part of his multifarious occupations, has shown both the desire and the capacity to give effect to my instructions.

(28.) *Charts.* The separation of the Drawing and Photozincographic branches, from the Calculating and Type-printing branches, already mentioned as having taken place early in the year, drew something of a line defining the obligations of the latter in respect of charts. The only ones with which we were concerned were those for which there was corresponding type-printing. I annex a list of these:—

N. W. Himalaya Degree Sheets, Index Map		
Do.	do.	Nos. 1 to 21 incl.
Eastern Frontier Series	Preliminary Chart	1874-75
Rámnád Longitudinal Series	do.	do.
Jodhpur Meridional Series	do.	do.
N E. Quadrilateral Extension, Skeleton Map		
S.E. Quadrilateral, 6 Series, 14 Plates.		

Reference has already been made in speaking of press copy, to the numerical data accompanying what are known as preliminary charts. These are drawn by the survey parties and contain, partly upon the face and partly in attached MS, the numerical results of the previous field-season. If possible the MS portion is set up in type and an impression placed upon the chart before it is photographed. If the available space is insufficient the matter in type is separately printed and attached in pamphlet form. It will readily be understood that the Computing Office is in this way to a certain extent responsible both for what appears upon and with the chart—not in respect of its numerical accuracy, which is provisional, but in regard to its general harmony. This gives rise to an indispensable scrutiny by which errors of minor consequence are sometimes detected. This is particularly the case with the orthography, descriptions, and nomenclature of stations which appear both upon the chart, and in the added matter—points in which we cannot expect perfect manuscript. It is not easy to define very clearly what share of the work thus indicated,—especially what share of the press work—is to be reckoned under the head of Charts. It would seem to claim everything which goes to the making of them, but obviously other classes have some claims on the process too.

(29.) There is one point in connection with this subject which ought to be noticed in a report. There is a steady demand—and I am bound to admit a quite legitimate one—on the part of the Drawing Office, for type-printed titles, foot-notes, &c., required for maps which are to be photographed.

These used to be attached in the Photo-Printing Office, but as they took the place of printing which would otherwise fall to the draughtsman, I suggested that it would be preferable that this should all be done in the Drawing Office, not only because it was proper that a map should be handed to the photographer complete, but because it seemed likely that by the exercise of a little foresight the petty demands on the printer would become condensed into larger and less frequent ones. This has I believe been found to be the case, and it is clear gain; because printed slips though a boon to the draughtsman are a drain on the printing power. They have long since been felt to be so much more wasteful than if the Drawing Office had its own printing appliances, that as long ago as August of last year—15 months ago—an emergent indent for I think £50 worth of plant was despatched through the Government of India to the Secretary of State. It was sanctioned; but to this day the type &c. have not been received, any more than have our own regular indents of a somewhat earlier date been met as yet. A part are I believe on their way—*viâ* the Cape.

(30.) *Meteorology.* The usual observations have been recorded without interruption, and reduced: monthly abstracts have been communicated to the Meteorological Reporter to the Government, N.W.P. The usual table of monthly means and a table of wind velocities as furnished by a self-registering anemometer on the Basevi Memorial Clock-Tower are appended. The wind directions indicated by the same are also self-registered and the sheets are available for investigations of the influence of barometric tides on the lower air currents; but the office is too full of work to allow of such being undertaken except by special desire of the Meteorological Office. Observations for time have been frequently taken, by Mr. Peychers, for regulating gunfire at Mussooree and the Basevi Clock at Dehra, as well as for chronometer rating.

(31.) *Library.* A library is nothing without a catalogue, and a catalogue is next to nothing which does not serve its purpose well. The only catalogue we possess is one which having outgrown the framework constructed by me in 1863 for a comparatively modest stock of books, calls urgently for reconstruction. The subject has been present to my mind for months; but though I have a well defined idea of what has to be done the large amount of writing which it will entail has prevented much progress. As a special memorandum on the libraries in public offices was circulated by the Government of India not long since, no apology is necessary for noting briefly here what occurs to me on the subject. The foundation of the Catalogue of the British Museum Library, as well as of that invaluable annual publication the "English Catalogue",—copy of which from 1831 to the present time I happen to possess—is an alphabetical arrangement by (1) author's name (2) leading word, where the work is anonymous or only edited. Cross references are most useful, but they must be quite subordinate, and must not interfere with the plan, which consists in having one full and complete entry for each work, in its alphabetical place. There must be ample room for fresh entries, but it is not desirable that these should be currently made, unless the custodian has some literary qualification. A day-book for current acquisitions provides sufficiently for the catalogue being properly filled up from time to time.

(32.) Having perceived that such a catalogue must be prepared if possible I stopped further entries in the existing *classified* catalogue, and instituted a day-book. This is a current account of books lent as well as received, and has been kept up since. It supplements, on the Cr. side—if it does not render unnecessary—the file of receipt notes; and on the Dr. side it shows or should try to show the title and description, in full, of new acquisitions, for use in bringing up the catalogue. I may add that this latter may possibly be created, if I am allowed time, without the resources of the office being drawn upon otherwise than for printed forms.

(33.) I have already remarked upon the crowded state which the Library and Record Rooms have reached. This partly arises from the constant influx of printed sheets of the Volumes of the Operations. The annual out-turn of the printing office is partly represented by 35 to 40 reams of double royal, of professional matter alone, all of which has, for a time at least, to be stored in one or other of the rooms of the office. This mass of paper occupies much accommodation, and tends to oust both records and books. If funds were available I should propose the substitution of iron racks of greater capacity for the present somewhat incommodious wooden stages, especially in the library, where I think space would be gained—and that without risk from white ants—by following the outline of the room instead of occupying its central area. The racks which have been erected in the observatory are excellent models—though of course they would require to be differently designed for a library.

(34.) *Correspondence.* This speaks for itself; but it does not include correspondence in connection with the preservation of stations, next to be described.

(35.) *Stations.* The business and correspondence connected with the protection of survey stations has for several years been conducted by Mr. Wood, under the direct control of the superintendent. Without at all desiring to interfere with an arrangement which, if it absorbs to an uncertain extent the attention of his principal assistant, yet at the same time relieves the officer in charge of much responsi-

bility, it nevertheless appeared precarious to leave the entire knowledge of the details at the mercy of events. Mr. Wood accordingly, by my direction, drew up an account of the routine, from which the following is condensed. There are three forms in regular use viz:—A, Custody Receipts; B, Annual and District Lists; C, Final District Lists. Custody Receipts are taken by executive officers from village officials at the time of handing over stations into their charge, and are transmitted to Head Quarters, where they are filed as vouchers. I do not gather that they serve any other purpose, in themselves, as they are annually incorporated in the lists B. These are prepared by the executive officers, in the first instance, irrespective of districts, as Annual Lists; and from them are compiled here, on the same forms, the District Lists, which are sent out to the civil officers, who revise and return them with their report on the condition of the stations which they are thus officially made cognizant of as existing within their jurisdictions. From one cause and another these district lists are at first incomplete and erroneous when sent, but when thus revised they ultimately supply all the requisite means for preparing the final lists C. These are then transmitted, along with blank forms, and the district officers, taking the final lists as guides, report annually on the spare forms, stating in an appropriate column the actual condition of each station, and if necessary the estimate of its repair.

(36.) The object of this procedure is clearly to secure a complete transfer of all stations to the care of the civil administration of the districts in which they are situated, and to provide for their continued preservation. The latter purpose is effected by an allotment from Imperial funds. An annual expenditure was some years ago sanctioned which at that time averaged 4 Rs. per station. The increase in the number of stations so transferred, without a corresponding increase in the allotment, has lowered this average; but it has been found possible, so far, to defray the requisite expenditure.

(37.) There are now 313 of these Final District Lists, disposing of some 2725 principal stations, leaving perhaps 30 districts in which it has not yet been possible to get beyond the preliminary stage. To keep the system up, and to arrange for the proper expenditure, entails of course much correspondence, and requires on Mr. Wood's part a very extensive knowledge of his subject.

(38.) Although the preparation of the Final District Lists managed in this way provides for the gradual rectification of local information regarding the positions of the several stations, it is I think a pity that it has not been made a means of obtaining the vernacular names of localities specified in the descriptions. This department is fully alive to the importance of setting a good example in the matter of orthography in its publications, and it might get much help in the annual reports from districts, were the spelling in these more attended to on the spot.

(39.) In close connection with the preservation of known stations, is the recovery and identification of old ones which have been lost sight of. Formerly—I am referring to the early days of the Survey—it seemed the natural fate of a station to die out and leave no sign. I remember one which had been thus allowed to pass out of existence for half a century, and its site only was recovered by digging about in a likely part of a ploughed field. Some disappear unaccountably, while sometimes later operations re-establish a station sensibly but not identically the same as an older one. All such incidents have—since Colonel Walker placed the preservation of Trigonometrical Survey stations on its present footing—been carefully noted in a book devoted to the purpose.

(40.) PRINTING OFFICE. The tabular analysis of monthly cost which has now been gone through does not include expenditure on printer's staff. That part of it which has been assigned to press proofs should be added to the cost of the printing establishment proper, if it were desired to estimate the cost of the printed matter published here. It would no doubt be possible to obtain in this way a proportional estimate of the cost of *composing and correcting* a page of type. But to extend this estimate to printed pages would involve a consideration of the number of pages, and would yield a result of doubtful accuracy. Moreover it would leave out of consideration everything connected with material and plant. I shall not therefore venture upon this, but will merely give a continuation of the usual statement of out-turn.

Year.	Pages composed (foolscap size).	Pages printed (all sizes).
1865-66	377	53 thousand
67	756	93 "
68	641	127 "
69	697	155 "
70	693	106 "
71	819	235 "
72	1143	241 "
73	1420	273 "
74	1220	388 "
75	1319*	373* "
76	1179*	349* "

* Averages for a twelvemonth.

The falling off in the last year is due to several causes—among which must be included my inexperience as a printer. In the early months the out-turn was very small, being chiefly professional matter of unusual kinds, and letterpress containing a good sprinkling of mathematical demonstration. Later on there was difficulty in composing well from the draft of the N. W. Himalaya Degree Sheets, as has been already explained. But it is needless to trace these fluctuations minutely, since out-turn must frequently depend upon causes beyond control. I should however mention that the severe illness of our printer Mr. O'Connor, which deprived the office of his services for 6 weeks, and the failing health and ultimate death of our best pressman—events which threw a severe increase of responsibility on Baboo Gunga Pershad who was superintending at Dehra during the time—cannot, I think, thanks to his exertions, be held to explain the decrease.

(41.) Mr. O'Connor has since taken sick leave and the charge of the printing establishment has devolved upon his chief compositor Nurbeer Singh, who carries on the work surprizingly well. I have also been fortunate in replacing the pressman satisfactorily.

(42.) I cannot close this report without an expression of regret that the close of this year will bring round for the second time the half yearly period when claims to increase of salary are considered, without my being able to submit any recommendations: not because none are worthy, but because retrenchment is ordered. I have no alternative but to claim for those under me the recognition which I myself tender them—of thanks for services faithfully performed.

Mean Velocity in miles of the winds which blew at Dehra during 12 months of 1875-76 for each hour of the day.

Civil Hours.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.
0 to 1	1·35	2·88	2·58	1·50	2·21	2·74	3·47	2·43	2·05	1·43	1·32	1·83
1 „ 2	1·32	1·85	2·10	1·32	2·14	1·97	2·57	2·05	1·62	1·07	1·55	1·33
2 „ 3	1·06	1·69	1·77	1·46	2·00	2·32	2·80	2·10	1·95	1·39	1·35	1·43
3 „ 4	0·84	1·35	1·81	1·36	2·03	2·10	1·67	1·57	1·57	0·79	1·29	1·43
4 „ 5	0·45	0·65	1·58	1·25	2·07	2·03	1·57	1·19	1·19	1·46	1·16	1·37
5 „ 6	0·22	0·54	1·48	1·32	1·97	2·06	1·53	0·81	1·10	1·29	1·06	1·13
6 „ 7	0·38	0·42	1·45	1·29	1·38	1·58	1·20	0·86	1·24	1·25	0·97	0·90
7 „ 8	0·03	0·35	1·13	1·04	1·28	1·29	1·10	0·95	1·43	1·18	1·06	0·40
8 „ 9	0·10	0·50	0·94	0·93	1·34	1·26	1·17	1·81	3·05	1·43	1·42	1·07
9 „ 10	0·23	0·65	1·43	1·00	1·93	2·00	1·90	2·33	3·55	1·46	1·61	1·27
10 „ 11	0·42	1·19	1·84	1·28	2·21	2·68	2·23	3·43	3·20	1·57	2·23	1·63
11 „ 12	1·10	1·46	2·23	1·48	2·31	3·29	3·33	4·62	3·85	2·04	1·71	1·90
12 „ 13	1·26	1·52	2·77	1·93	3·10	3·87	3·80	4·59	4·14	2·45	1·90	2·00
13 „ 14	1·13	1·81	2·65	2·04	3·28	3·90	3·53	4·55	5·00	2·72	2·19	2·10
14 „ 15	1·35	2·00	2·81	2·30	3·72	4·29	3·63	5·32	6·10	2·69	2·35	2·63
15 „ 16	1·13	1·69	2·74	2·68	4·24	3·94	4·00	4·73	6·33	2·62	2·10	2·17
16 „ 17	0·74	0·58	1·03	1·86	3·72	3·71	3·40	5·18	6·00	2·14	1·90	1·67
17 „ 18	0·52	0·27	0·45	0·43	1·62	2·71	2·87	3·41	4·52	2·17	1·26	1·10
18 „ 19	0·74	1·46	0·97	0·68	1·10	1·06	1·20	2·91	4·43	1·17	0·90	1·23
19 „ 20	1·06	2·65	1·97	1·29	1·24	1·32	1·57	2·32	2·10	1·03	0·81	1·40
20 „ 21	1·39	3·12	2·74	1·64	1·97	2·00	3·17	2·77	1·00	1·07	1·00	1·47
21 „ 22	1·55	3·12	2·32	1·79	2·17	2·26	3·57	3·09	1·35	1·10	1·19	1·73
22 „ 23	1·42	3·19	2·87	1·96	2·38	2·61	3·53	3·14	1·65	1·79	1·19	1·80
23 „ 24	1·39	3·19	2·68	1·64	2·48	2·26	3·63	2·45	1·85	1·28	1·23	1·73
Sums, ...	21·68	38·13	46·36	35·56	53·89	59·25	62·44	68·61	70·27	38·59	34·75	36·72
Averages, ...	0·90	1·59	1·93	1·48	2·25	2·47	2·60	2·86	2·93	1·61	1·45	1·53

MONTHLY Meteorological results taken from the Register kept at the Office of the Superintendent, G. T. Survey of India, Dehra Dún.

YEAR & MONTH.	BAROMETER. h. m. At 9 30 A.M.			BAROMETER. h. m. At 3 30 P.M.			HYGROMETER. h. m. At 9 30 A.M.		HYGROMETER. h. m. At 3 30 P.M.		THERMOMETER. Dry Bulb.					THERMOMETER. Wet Bulb.			RAIN.		WIND.	CLOUD. h. m. At 9 30 A.M.	CLOUD. h. m. At 3 30 P.M.
	Highest.	Lowest.	Monthly mean.	Highest.	Lowest.	Monthly mean.	Monthly mean Temperature of Dew point.	Monthly mean Humidity.	Monthly mean Temperature of Dew point.	Monthly mean Humidity.	Max: in Sun's rays.	Min: on grass.	Max: in air.	Min: in air.	Monthly mean in air.	Max: wet.	Min: wet.	Monthly mean wet.	No. of days it fell.	Fall in inches.	Most frequent direction.		
1875.	in.	in.	in.	in.	in.	in.	°	·	°	·	°	°	°	°	°	°	°	°					
October ...	27·802	27·527	27·686	27·716	27·460	27·606	61·2	·699	62·1	·568	99·6	51·1	83·6	54·0	70·1	74·8	45·2	61·1	4	1·19	N.W.	1	2
November	·908	·714	·800	·856	·662	·722	53·1	·675	54·1	·510	92·4	44·0	79·3	47·1	63·5	65·0	41·6	53·7	0	0·00	N.	1	2
December	·961	·744	·824	·844	·656	·735	46·8	·667	48·5	·495	87·8	36·2	76·7	40·2	57·9	63·6	36·5	49·5	1	0·05	N. & W.	2	2
1876.																							
January ...	27·861	27·607	27·742	27·818	27·530	27·667	44·3	·701	45·7	·494	83·1	24·2	74·7	38·1	55·7	60·0	30·3	47·3	3	1·40	W.	4	4
February ...	·836	·594	·699	·767	·507	·623	43·7	·616	42·6	·375	91·9	29·8	79·6	33·0	59·0	60·3	29·7	46·6	4	0·52	W.	2	4
March ...	·793	·493	·649	·731	·435	·573	49·7	·566	49·3	·398	98·0	43·2	86·3	46·2	65·2	64·0	36·7	52·3	4	1·65	W.	3	5
April ...	·716	·409	·551	·620	·322	·467	51·7	·414	49·2	·288	115·7	41·5	100·2	50·6	75·5	73·5	39·8	55·8	2	1·49	W.	1	2
May ...	·635	·376	·490	·536	·286	·403	58·3	·397	57·4	·298	116·0	58·9	102·0	61·8	83·7	91·7	50·9	64·9	4	1·44	N. & W.	2	3
June ...	·507	·269	·376	·421	·162	·289	65·7	·641	61·6	·563	118·5	61·8	106·8	65·5	88·8	80·5	58·0	69·4	5	1·37	W.	1	3
July ...	·454	·238	·348	·363	·157	·281	74·8	·853	75·5	·779	115·0	69·8	105·2	72·2	81·2	80·4	63·1	73·7	23	30·73	S.	9	8
August ...	·618	·296	·463	·531	·249	·390	74·0	·859	75·4	·813	105·5	66·0	89·0	69·8	78·7	81·0	57·0	72·2	21	27·28	S.E.	8	7
September ...	·732	·444	·572	·628	·359	·488	71·4	·796	73·4	·776	105·0	62·6	90·7	65·1	77·7	80·7	55·2	68·5	15	12·73	N.	6	6
October ...	·830	·581	·738	·763	·488	·651	60·2	·731	61·2	·606	98·2	49·5	84·3	53·2	68·6	72·5	41·0	58·5	8	4·00	N. & S.	2	3

NOTE.—The height of the Barometer Cistern above Mean Sea Level at Karáchi is 2232·41 feet.

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

INDEX TO MAIN LEVEL LINES WITH G. T. SURVEY FOR COMPILATION OF CHARTS.

XIII. Extract from the Narrative Report—dated 22nd December 1876—of Captain H. R. THUILLIER, R.E., Officiating Deputy Superintendent 1st Grade, in charge of Drawing and Photozincographing Branches of the Computing Office.

In consequence of Mr. Cole proceeding on furlough, I was directed to take charge of the Drawing and Photozincographic Branches of the Computing Office and assumed their direction on the 21st March.

It is necessary to state that the return of work executed in these two branches is for a period of twelve months, and therefore it is not comparable with that submitted in the preceding report, which embraced a period of 17 months for reasons therein stated.

DRAWING BRANCH.

Annual Return of work executed in the Drawing Office, during the year ended 30th September 1876.

DESCRIPTION OF WORK.	Number of sheets or diagrams. Finished	In hand	Scale 1 inch =	REMARKS.
Compilation.			*Miles*	
Map to illustrate the report on the Pandit's route through Great Tibet in 1874. Sheets 1 and 2, with hill shading.	2	...	16	For Photozincography.
Index Chart to the Degree Sheets of the N.W. Himalaya Series triangulation, with hill shading.	1	...	24	Do. Reduction to ¾ scale.
Map of Havildar, and Mullah's routes through Afghanistan &c., 1873-74.	1	...	16	Do.
Sheet No. 6 of Spirit Levelled Heights... ...	1	...	2	Do.
Do. „ 13 Do.	...	1	2	Do.
Do. „ 19 Do.	...	1	2	Do.
Do. „ 21 Do.	1	...	2	Do.
Do. „ 23 Do.	1	...	2	Do.
Do. „ 25 Do.	1	...	2	Do.
Do. „ 26 Do.		1	2	Do.
Do. „ 27 Do.	1	...	2	Do.
Do. „ 28 Do.	1	...	2	Do.
Do. „ 40 Do.	1	...	2	Do.
Do. „ 41 Do.	1	...	2	Do.
Do. „ 42 Do.	1	...	2	Do.
Do. „ 45 Do.	1	...	2	Do.
Do. „ 53 Do.		1	2	Do.
Do. „ 59 Do.		1	2	Do.
Do. „ 66 Do.	1	...	2	Do.
Do. „ 1 Dehra Dún and Siwáliks with hill shading,	1	...	1	Do.
Do. „ 2 Do. Do.		1	1	Do.
Do. „ 24 Do. Do. Survey. ...		1	½	Do.
Final Charts.				
Great Arc Series, Section ; 18° to 24°.	2	...	4	Do. Reduction to ½ scale.
Calcutta Longitudinal Series.	3	...	4	Do. Do.
East Coast Series.	2	...	4	Do. Do.
Bilaspur Meridional Series.	2	...	4	Do. Do.
Jabalpur Meridional Series.	2	...	4	Do. Do.
Bider Longitudinal Series.	2	...	4	Do. Do.
Degree Charts of the North-West Himalaya Triangulation. ...	14	...	4	Do. Do.
Miscellaneous.				
Examined and reported on 41 fair original Maps of Kumaun and Garhwál, Kattywar, Guzerat and Dehra Dún and Siwáliks Surveys.	...	...	...	
Examined 113 proofs of Maps and Charts. ...	...	...	...	
Colored 8,502 Maps.	...	...	...	
Prepared 7 professional and office forms on drawing and transfer paper.	...	...	....	For Photozincography and Zincography.
Prepared a trace on linen of the Assam Valley Triangulation 1875-76.	...	...	...	
Prepared a trace on linen of country round the Chur Peak. ...	...	...	...	
Prepared an Index Chart of Triangulation of N.E. Quadrilateral eastern extension.	...	...	...	For Photozincography.
Prepared 68 Figures of the several series contained in the S.E. Quadrilateral to illustrate G.T.S. Volumes. ...	...	...	...	
Prepared 97 Diagrams and Descriptions of Bench-Marks for Sheets Nos. 6, 21, 25, 27, 28, 40, 41, 42, 45, and 66 of Spirit Levelled Heights.	...	...	...	The diagrams for Photozincography. and reduction to ¼ scale.
Prepared tracings for use of various Officers and for record, and performed other miscellaneous duties. ...	...	...	...	

This Office has been principally engaged in the preparation of charts of triangulation, of which 27 have been completed, and of the series of Level charts, in which considerable progress has been made. Twelve of these sheets have been completed and four are very nearly ready for the press.
The accompanying Index map shows the sheets that have been published. The map of Northern Afghanistan showing the results of the explorations of the Havildar and the Mullah, and that of the Pandit's surveys through Great Tibet, both compiled under Captain Trotter's supervision, were completed early in the year, but circumstances of which you are aware, have prevented the publication of these very interesting maps.

A large amount of miscellaneous work has been done in addition, and I am glad to be in a position to say that Mr. Atkinson, the Chief Draftsman, conducts this small branch with much efficiency and energy.

PHOTOZINCOGRAPHIC BRANCH.

The amount of work executed by this Office for the year ended 30 September 1876 is shown hereafter under the heads of Charts, Diagrams, Forms, and Maps. This work may be briefly summarized as follows:—

109 transfers have been made to zinc, 25,425 complete prints of maps and other subjects and 18,314 copies of Forms have been struck off, besides the preparation of 126 silver prints.

The out-turn bears favorable comparison with that of former years, which can be seen by reference to the abstract given in the last report by Mr. Cole, and taking into consideration the reductions which have been carried out both in this and in the Drawing Branch during the year under review, I trust the returns of these small Offices will be considered satisfactory both in quantity and quality.

In the Photozincographic Office Mr. Ollenbach continues to merit the good opinion previously expressed of his industry and supervision, while the subordinates in both branches have as a body worked satisfactorily.

Charts.

SUBJECT.	When published.	No. of parts.	No. of copies printed.
Jogí-Tílá Meridional Series Chart, Final	October 1875	1	369
Sutlej Series Chart, Final	November „	1	366
North-West Himalaya Series, Degree Sheet 1—2, Final	February 1876	1	370
„ „ „ „ „ 3—4, „	„ „	1	367
Jodhpur Series, season 1874-75, Numerical	March „	1	68
Rámnád Longitudinal Series, Season 1874-75, Numerical	April „	1	68
Eastern Frontier Series, season 1874-75, Numerical	August „	1	70
	Total ...	7	1678

Diagrams.

SUBJECT.	When published.	No. of copies printed.
Plates to illustrate Volumes of the G.T. Survey, and other Diagrams	October 1875	151
	November „	899
	December „	502
	January 1876	1537
	February „	82
	April „	1262
	May „	1026
	June „	1918
	July „	742
	August „	1253
	September „	350
	Total ...	9722
Professional and Office Forms	1875-76	18,314

Maps.

SUBJECT.	When published.	No. of parts.	No. of copies printed.
Prints of maps published in former years	...	22	1852
Kumaun and Garhwál, sheet No. 12, contoured	October 1875	1	119
" " " 22, "	" "	1	109
Guzerat Survey, sheet No. 80, section 4	" "	1	107
" " " " " 6	" "	1	107
" " " " " 10	November "	1	105
" " " " " 14	" "	1	108
Index to Guzerat Survey	" "	1	415
" Kattywar "	" "	1	444
" Dehra Dún and Siwalik Survey	" "	1	454
Dehra Dún and Siwalik Survey, sheet No, VI	" "	1	143
" " " " VII	" "	1	137
" " " " XV	" "	1	147
Kumaun and Garhwál, sheet No. 21, skeleton	" "	1	164
" " " 6, contoured	December "	1	103
" " " 38, "	" "	1	105
Kumaun Map / Garhwál " } For N.W. Provinces' Gazetteer	" "	1	1451
Dehra Dún and Siwalik Survey, sheet No. I	" "	1	1281
" " " " III	" "	1	148
" " " " V } For Forest Department	" "	1	152
" " " " XI	" "	1	132
" " " " XII	" "	1	136
" " " " XIII	" "	1	136
" " " " XIV	" "	1	139
" " " " XXI For Forest Department	" "	1	142
Map illustrating the Pandit's route in 1874	" "	1	135
Index to Kumaun and Garhwál Survey	" "	2	454
Dehra Dún and Siwalik Survey, sheet No. 11	January 1876	1	444
Kumaun and Garhwál, sheet No. 23, skeleton	" "	1	140
Kattywar Survey, sheet No. 42	" "	1	159
" " " 43	" "	1	127
" " " 31	February "	1	143
Kumaun and Garhwál, sheet No. 26, skeleton	" "	1	132
" " " 6 " 2nd edition ...	" "	1	159
Map illustrating the Havildar's routes 1873-74	" "	1	157
Kattywar Survey, sheet No. 44	" "	1	481
Map of Khota Bhabur	March "	1	137
Kamaun and Garhwál, part of sheet No. 17 contoured	" "	1	34
Dehra Dún and Siwalik Survey, sheet No. IV } For Forest Department	" "	1	34
" " " " No. IX }	" "	1	130
Guzerat Survey, sheet No. 80, section 12	" "	1	140
" " " " 6	" "	1	127
" " " " 15	April "	1	104
" " 81 " 3	" "	1	106
Index to North-West Himalaya Series Degree Sheets	May "	1	107
" Triangulation, N. E. Quadrilateral Eastern Extension ...	June "	1	399
Spirit Levelling operations, No. 66	" "	1	10
" " 23	July "	1	120
" " 27	" "	1	119
Guzerat Survey, sheet No. 81, section 2	" "	1	133
" " " " 4	August "	1	109
" " " " 10	" "	1	113
Kumaun and Garhwál, sheet No. 1, skeleton, 2nd edition, ...	" "	1	110
Mussooree and Landour Survey, sheet No. 14, skeleton, 2nd edition ...	" "	1	162
Spirit Levelling operations, No. 28	" "	1	35
" " " 40	" "	1	112
" " " 46	" "	1	110
Guzerat Survey, sheet No. 81, section 5	September "	1	115
" " " " 12	" "	1	109
Spirit Levelling operations, No. 6	" "	1	95
" " " 21	" "	1	115
Dehra Dún and Siwalik Survey, sheet No. VIII	" "	1	122
" " " " XLII	" "	1	9
	" "	1	142
	Total ...	86	14,025

Besides the foregoing, 12 Blue prints were issued, and 126 sets of Silver prints (50 subjects) were prepared on the scale of the Indian Atlas for the use of the Engravers and for Executive Officers.

Nos. 235—237.

Extract from the Proceedings of the Government of India in the Department of Revenue, Agriculture, and Commerce,—dated Simla, the 16th April 1877.

SURVEYS.

READ—

Report on the operations of the Great Trigonometrical Survey for the year 1875-76.

RESOLUTION.

OBSERVATIONS.—The operations of the year were for the most part in continuation of those carried on during 1874-75. The five trigonometrical parties were engaged in the same fields as in that year: the topographical parties also pursued their work in Guzerat, Kattywar and Dehra Dún; no surveys in Kumaun and Garhwál were carried out in 1875-76, but these have lately been resumed during the current year. In the other classes of work, the report for 1875-76 omits only the section on Trans-Himalayan explorations and that on spirit-levelling in the Madras Presidency: the latter work was completed last year, and Captain McCullagh, the officer in charge of it, was detached for duty on the topographical survey of Mysore.

2. Of the five trigonometrical parties three were engaged in principal and secondary, and two only exclusively in secondary triangulation; work of the latter description was also done in the ordinary course of their operations by the three parties employed on topographical surveys. The outturn as compared with last year was as shewn below:—

		1874-75.	1875-76.
Principal triangulation—			
Area in square miles	...	6,416	4,182
Direct length in miles	...	297	217
Number of triangles	...	89	48
Number of stations fixed	...	63	38
Secondary triangulation—			
Area in square miles	...	10,075	9,413
Number of triangles	...	455	363
Number of stations fixed	...	358	633*

3. These figures shew a considerable falling off in the outturn of work as compared with 1874-75. As regards principal triangulation, the decrease is manifest in the outturn of the parties engaged in the Rámnád longitudinal and the Jodhpur meridional series: the party at work on the Eastern Frontier series yielded an outturn fully equal to the excellent result obtained last year. The first of the two parties whose outturn was deficient was engaged in peculiarly difficult and tedious work,—the connection of the Indian triangulation with that of Ceylon over the intervening islands and reefs in Palk Straits, and that connection has now been satisfactorily established. The second completed the Jodhpur meridional series on which it was employed, and thus had no work left to do in that region: it was also engaged on a new series in Sind, and its outturn was reduced by the inevitable delays of changing ground (aggravated by sickness), and starting a new scheme of operations.

4. The secondary work is of two descriptions: first, that subsidiary to the principal triangulation and the topographical surveys; and secondly,

* These figures are taken from the abstract given at page 29 of the report; the headings of this statement do not in many cases agree as regards secondary triangulation with those given in the statement in the report for 1874-75, and therefore the work of the two years cannot be compared with the detail that would be desirable. The Superintendent is requested in future to make the statement comparative, and to shew in it the total outturn of the previous year, as well as of the year reported on.

triangulation carried out by means of smaller theodolites, and not, as in the principal triangulation, with great theodolites, for the purpose of fixing points in regions, as Assam and Burma, where their determination is required to enable other surveys to be started; the latter class of work is, as explained by Mr. Hennessey, in no other respect than the more portable and smaller instruments with which it is performed inferior to the principal triangulation. The Assam party cleared 250* miles of rays in 1875-76 against 106 in the previous year, measured 13 triangles, and selected 35 stations: the Superintendent states that the outturn is "not only large, but, so far as he has means of judging, has been well executed." The Burma party under Mr. Beverley completed the very satisfactory amount of 3,600 square miles, besides fixing a large number of heights, in a country where work is carried on under considerable difficulties. The differences between the outturn in secondary work of the other parties during this year as compared with 1874-75 do not call for remark.

* According to the statement in page 29. In the body of the report at page 7 the distance is given at 192 miles, and the 37 miles of the previous season's cutting, which it is said that it was necessary to re-open, do not explain the discrepancy.

5. The area covered by topographical surveys executed during the year compares as follows with that of 1874-75 :—

	1874-75. Square miles.	1875-76. Square miles.
Dehra Dún, on 4-inch scale	225	124
" " 2 "	...	430
Kattywar, " 2 "	1,749	2,253
Guzerat, " 4 "	983	924
" " 2 "	392	948
TOTAL	3,349	4,679

In addition to the outturn here shewn, however, 2,176 square miles were in 1874-75 topographically surveyed in Kumaun and Garhwál on the one-inch scale. The comparison between the two years is satisfactory. The Dehra Dún survey (including Jaunsár Báwar) has now been completed, with the exception of about 20 square miles which remain to be surveyed by the Forest Survey Department. It is however observed that no particulars are given of the progress made in surveying by the Native agency, to train whom for work in the higher regions this survey was partly undertaken; it would seem from the fact that of seven Native Surveyors only one was employed in Jaunsár Báwar, while the other six had to be provided with work in a 12-inch survey of the town of Dehra and its environs, that they have not acquired so much proficiency as was hoped for. The Governor General in Council will be glad to learn whether it has been found possible to employ them in the survey, resumed this year, of the higher tracts of Kumaun and Garhwál. The other two surveys shew a considerably larger outturn this year than last. The orders for the reduction of the 4-inch survey in Guzerat to a 2-inch scale were, it is said, not received in time for the reduction to that scale of the work in the field, but the maps will be drawn to the smaller scale.

6. The spirit-levelling operations in Cutch and Kattywar carried out by Captain Baird, and the electro-telegraphic determinations of longitude made by Captains Campbell and Heaviside were satisfactorily performed, and the progress made in the computation and publication of results was also worthy of praise. The charts of spirit-levellings now being issued promise to be of great value for the purposes of other Departments than the Survey.

7. The retirements of Colonel Montgomerie, who has so long superintended the Trans-Himalayan explorations made by employés of the Department, and of Mr. Rossenrode, of whose successful labours in Burma the reports for this and last year contain a most creditable record, are noticed in suitable terms by Mr. Hennessey, and the Governor General in Council heartily joins in the acknowledgments of these officers' eminent services contained in the report.

8. The attention of the Chief Commissioner of British Burma is invited to paragraph 22 of Mr. Beverley's narrative report (page 11-a), in which

mention is made of the delay and expense caused by the refusal of the Deputy Commissioner of Prome to give the Surveyors a parwána to aid them in obtaining aid and supplies. As parwánas were granted without objection by the district officers of Rangoon, Henzada and Thayetmyo and the Commissioner of Tenasserim (page 15-a), it is presumed that they involved no unreasonable exercise of authority, and it is stated that where granted they contributed greatly to facilitate the operations of the party.

9. Paragraph 8 of Mr. Ryall's report (page 30-a), regarding the imperfect definition of the boundaries of the Chakráta Cantonment, will be brought to the notice of the Military Department.

ORDER.—Ordered, that copy of this Resolution be forwarded to the Superintendent of the Great Trigonometrical Survey of India for information.

Ordered also, that copy of this Resolution, with a copy of the report, be forwarded to the Chief Commissioner of British Burma with special reference to paragraph 8.

Also, that a copy of the Resolution, with a copy of the report, be forwarded to the Military Department with special reference to paragraph 9.

(True Extract.)

G. H. M. BATTEN,

Offg. Secretary to the Government of India.

1877

DEPARTMENT OF REVENUE, AGRICULTURE, AND COMMERCE.

SURVEYS.

RESOLUTION.

Nos. 235—237.

Dated Simla, the 16th April 1877.

SUBJECT.

REVIEW of the report on the operations of the Great Trigonometrical Survey for the year 1875-76.

Govt. Central Branch Press, Simla.—No. 55, R., A. & C.—20-4-77.—100.

GENERAL REPORT

ON THE OPERATIONS OF

The Great Trigonometrical Survey of India,

DURING

1876-77.

PREPARED FOR SUBMISSION TO THE GOVERNMENT OF INDIA,

BY

COLONEL J. T. WALKER, C.B., R.E., F.R.S., &c.,
SUPERINTENDENT OF THE SURVEY.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT OF GOVERNMENT PRINTING.
1878.

AY BRANCH
OF THE
Royal Asiatic S
CLASS

INDEX CHART
TO THE
GREAT TRIGONOMETRICAL SURVEY
OF
INDIA

SHOWING COLONEL LAMBTON'S NET WORK OF TRIANGULATION IN SOUTHERN INDIA,
THE MERIDIONAL AND LONGITUDINAL CHAINS OF PRINCIPAL TRIANGLES
THE BASE LINES MEASURED WITH THE COLBY APPARATUS,
THE LINES OF THE SPIRIT LEVELLING OPERATIONS,
THE ASTRONOMICAL, PENDULUM & TIDAL STATIONS,
AND THE SECONDARY TRIANGULATION TO FIX THE PEAKS OF
THE HIMALAYAN & THE SOOLIMANI RANGES.
Completed to 1st October 1877.

Scale 96 Miles = 1 Inch. or 1:6336000

REFERENCES

The course of the levelling operations is shown by a dotted line
The stations where the Latitude has been observed astronomically by a star
The stations where an Azimuth has been observed astronomically thus +
The Pendulum stations thus
The Principal triangulation done in Southern India before the year 1830 is shown by lines lighter than over by thick lines.
No Secondary triangulation is shown excepting that to the peaks of the mountains on the northern frontier.

BAY OF BENGAL

ANDAMAN ISLANDS

CEYLON

68° 72° 76° 80° 84° 88° 92° 96° 100°

32° 28° 24° 20° 16° 12° 8°

C. DYSON, PHOTO.

COMPILED UNDER THE ORDERS OF COL. J.T. WALKER R.E., F.R.S. &c SUPERINTENDENT GREAT TRIGONOMETRICAL SURVEY OF INDIA AT DEHRA DOON, AUGUST 1870

Photozincographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Dún, November 1877.

C. O. OLDERSHAW, SURVO.

GENERAL REPORT

ON THE OPERATIONS OF

The Great Trigonometrical Survey of India,

DURING

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BY

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GENERAL REPORT

ON THE OPERATIONS OF THE

Great Trigonometrical Survey of India

IN

1876-77.

THE several operations of the present year, taken in the order in which they are described in this Report, are as follow :—

			Page of Report.	Page of Appendix.
No.	I.—*Trigonometrical.*	The Madras Coast Series ...	3	3—a
,,	II.—*Trigonometrical.*	The Secondary Triangulations in the Assam Valley ...	4	9— "
,,	III.—*Trigonometrical.*	The Secondary Triangulations in Burmah	5	12 "
,,	IV.—*Trigonometrical.*	The Eastern Frontier Series, Moulmein	6	14—"
,,	V.—*Trigonometrical.*	The Eastern Sind Series, Meridian 70°	7	16 "
,,	VI.—*Topographical.*	The Survey of Kattywar ...	7	17 "
,,	VII.—*Topographical.*	The Survey of Guzerat ...	8	21 "
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,,	XIV.—*Head Quarters Offices.*	Computing; Printing; Drawing; Photozincographic; Correspondence; and Stores ...	23	56—"

(2.) The operations carried on during the year under review have produced the following out-turn of work. *Principal Triangulation :* 67 triangles have been measured, fixing 53 new stations and covering an area of 5,019 square miles, in three series or chains, which, if united, would extend over a direct distance of 269 miles; astronomical azimuths of verification have been measured at two of the principal stations. *Secondary Triangulation :* an area of 5,100 square miles has been closely covered with points for the topographical survey; an area of 3,100 has been operated in *pari passu* with the principal triangulation; and in an area of about 23,600 square miles, lying mostly in portions of the Himalayas which are inaccessible to Europeans, a number of points have been fixed which will be valuable for geographical rectifications. *Topography :* areas of 959 and 610 square miles have been completed, on the respective scales of half an inch and one inch to the mile, in the British portions of the higher Himalayas; and an area of 3,704 square miles has been completed, on the two-inch scale, in portions of the Bombay Presidency, in the course of which 2,717 linear miles of boundary and check lines were surveyed. *Geodetic Operation :* the amplitudes of three arcs of parallel, between trigonometrical stations in Southern India, were determined by the electro-telegraphic method; and the differences of longitude between Bombay, Aden, and Suez have also been determined in the same manner. *Geographical Explorations :* much valuable work has been done on the unsurveyed portion of the River Indus, and in and around the Kohistan which contains the sources of the Swat and the Panjkora rivers.

(3.) The principal triangulation has been executed in the usual manner with the great theodolites—instruments whose azimuthal circles have diameters of either 36 or 24 inches. The average theoretical probable error of the angles, as deduced from the evidence of the several measures of each angle,—and the average geometrical error of the triangles—the amount by which the sum of the three angles of each triangle exceeds or is in defect of 360° + the spherical excess—are shown in the margin, for each of the three series in which principal triangulation was carried on during the present year.

Series described in Section	Probable errors of observed Angles.		Geometrical errors of Triangles.	
	Number.	Magnitude.	Number.	Magnitude.
I ..	51	±0″·17	18	0″·81
IV ...	31	·42	17	·46
V ...	96	·14	32	·36
Averages ...	..	0″·20	...	0″·51

(4.) The administration of the department during the year devolved first on Major H. R. Thuillier, R.E., from the 4th April to 31st October 1876, and afterwards on J. B. N. Hennessey, Esq., M.A., F.R.S., &c., from the latter date until the 13th January 1877, during my absence in Europe on furlough. The report for last year was drawn up by Mr. Hennessey.

(5.) I now proceed, as usual, to report on, and give an abstract of, the several operations. Further details will be found in the extracts from the Narrative Reports of the Executive Officers, which are given in the Appendix.

No. I.—TRIGONOMETRICAL.

THE MADRAS COAST SERIES.

(6.) The charge of the Madras Party was taken over by Captain Carter, R.E., on his return from furlough on 20th November 1876, from Captain Campbell, R.E., who had held it as a temporary measure during the recess, on Major (now Lieutenant-Colonel) Branfill's departure to Europe in May.

PERSONNEL.
Captain T. T. Carter, R.E., Deputy Superintendent, 3rd Grade.
Mr. G. Belcham, Surveyor, 4th Grade.
„ C. D. Potter, Assistant Surveyor, 1st Grade.
„ A. H. Bryson, „ „ 3rd „

(7.) Captain Carter lost no time in making his preparations for taking the field, and he reached the scene of his operations by 1st December. During the preceding season, nearly all the stations had been chosen and built for two hexagons in advance of the final triangulation. Captain Carter's first care was to complete these stations, choosing definitely those which remained doubtful, clearing the rays where necessary, and building the pillars and scaffoldings for the instrument and signallers. He then took up the final triangulation, and during the season completed these two hexagons, and a third which his assistants had selected and prepared in the meantime. The season's work also included the selection and building of stations, and the clearance of rays for another hexagon in advance of those finally observed; and one astronomical determination of azimuth.

(8.) The country is very unfavourable for triangulation, being flat, with innumerable groves of valuable trees. The villages are numerous, and each covers a great quantity of ground; locomotion, moreover, is by no means easy, owing to the want of roads. The famine, which was raging in Southern India during the season, made the question of supplies a difficulty; prices being excessively high, and the inhabitants sometimes unwilling to provide food at any price offered. During the beginning of the season, a water famine also seemed imminent, and there was a good deal of cholera in the district. Considering that the country was new to him and the difficulty he met with, the out-turn of work is very creditable to Captain Carter, who was, as he reports, well seconded by his assistants.

(9.) To obviate the necessity of heavy expenditure in building towers at the stations, Lieutenant-Colonel Branfill had introduced in the previous season a system of raising the signals on lofty scaffoldings, and the theodolite on a high tripod-stand of wood. This system was followed by Captain Carter, the signal being generally raised 45 feet, and on one occasion as high as 60 feet, from the ground, while the theodolite was generally raised about 24 feet. The system requires extra care on the part of the signallers in plumbing their signals over the station-marks, but it has been found to work well; and it certainly effects a considerable saving of expense, for it enables the triangulation to be carried on without the construction of substantial masonry pillars raised to a height of 20 to 30 feet above the general level of the plains, as is otherwise necessary. The advantages from an economical point of view have, however, been allowed rather more weight than is altogether desirable. The principal stations have been raised to a height of only one or two feet above the ground-level, which is scarcely sufficient to enable them to be readily identified many years hence, when the present generation has passed away, as it is desirable that they should be. Instruction have therefore been issued to Lieutenant-Colonel Branfill to raise all stations situated on level ground to a height of not less than 10 feet, and then to erect the tripod for the theodolite, or the scaffolding for the signals, on them. Thus the requisite command of view will be secured by temporary arrangements without undue sacrifice of prominence and permanence in the structure of the stations.

(10.) The nature of the country precluded the possibility of executing much secondary triangulation, but whatever was practicable was accomplished. Captain Carter endeavoured to find all the stations of the old triangulation by

Colonel Lambton, which he knew to be in his neighbourhood, with a view to their incorporation in his own triangulation; but in only one case was he successful. This points to the importance of carefully marking the principal stations of this Survey at the outset; it is now evident that this was not sufficiently attended to originally.

(11.) Lieutenant-Colonel Branfill returned from furlough, and relieved Captain Carter of the charge of the party, on the 1st June 1877. The reductions of the observations, and the construction of the preliminary chart, have been completed under his supervision. He has also prepared a list of the commonplace names met with in the districts operated in, with their traditional root-meanings and local applications, which is very interesting; it will be found at page 5—a of the Appendix.

No. II.—TRIGONOMETRICAL.

THE SECONDARY TRIANGULATION IN THE ASSAM VALLEY.

(12.) These operations have been carried on by Lieutenant Harman, R.E., with his customary energy, and, on the whole, with good results, notwithstanding the many difficulties met with.

PERSONNEL.

Lieutenant H. J. Harman, R.E., Officiating Assistant Superintendent, 2nd Grade.
Mr. O'Sullivan, Surveyor, 4th Grade.
„ J. F. McCarthy, Assistant Surveyor, 4th Grade.

(13.) It was mentioned in the general report for 1875-76 that two hill-peaks affording desirable sites for survey stations were unfortunately in the Abar territory, and that the permission of the Abar chiefs to visit them had been sought in vain. During the past season arrangements were sanctioned by the Government to permit of Lieutenant Harman's visiting these peaks with an escort of 100 men of the 44th S. L. I. This measure was carried out successfully, and, although confined to the two hills in question—Dipa and Nari by name—afforded valuable results, enabling a large amount of line-cutting to be avoided which would have been necessary had the triangulation been restricted to the plains. Topographical sketches were also obtained of about 100 square miles of plain country and 300 square miles of hills, hitherto unsurveyed.

(14.) Much heavy work was necessary in clearing the rays, and, as in many cases the lines led through tea-estates, great care was required to spare valuable trees and avoid liability for compensation. Lieutenant Harman remarks that Mr. O'Sullivan, who did most of the clearing, deserves credit for his economy in this respect; very lofty signalling scaffoldings were occasionally employed. The weather was frequently very unfavourable for observing, or indeed for field-work of any kind, as there were many days of incessant rains, which not only flooded the nullahs and turned the forest-paths into streams of mud and water, but brought out myriads of leeches which caused the greatest annoyance. Much cane-jungle was met with at times, which is difficult to break through even with elephants, and causes very slow travelling in the case of bare-legged natives. On one occasion a large cargo-boat belonging to the party was swamped in a storm on the river Dihang, and, although recovered once, was swept away again, and sank finally. A case of records which went down with the boat was fortunately recovered by a Miri with a spear.

(15.) Lieutenant Harman mentions meeting with magnificent specimens of rubber trees, which sometimes caused great delay when it was necessary to fell them. One of these trees, which was on the top of a forest-clad hill, was of much use, as it afforded the means of obtaining a station at a height of 112 feet above the ground, for the purpose of connecting Lieutenant Harman's triangulation with that of Lieutenant Woodthorpe, R.E., who was carrying on a topographical survey in the neighbourhood.

(16.) The work of the season comprised the final observations of 19 triangles, extending over a distance of 53 miles, along the banks of the Brahmaputra river to within a few miles of Sadiya; the sides being made short in order

to minimize the difficulties of line-cutting, the area covered was only 240 square miles; 125 miles of new rays were opened, and 16 stations built in this triangulation. On the secondary series, "Dibrugarh-Jaipur," 3 triangles were completed, which embrace 75 square miles and entailed 63 miles of ray clearing. The positions of 110 peaks on the surrounding hill-ranges have been fixed by intersections, and the heights of 92 of these peaks were determined.

(17.) The health of the party was generally good. Lieutenant Harman himself, however, suffered from a slight sunstroke at one time, and towards the end of the season he was thoroughly knocked up and became very ill. He would then have had to take leave of absence on medical certificate, but that I summoned him to the Head Quarters at Mussooree. Here he completed a considerable portion of the computations connected with the work of the previous field-season, and prepared various programmes for geographical explorations in connection with the work of the next season, which were successively submitted for the consideration of the Government of India and the Chief Commissioner of Assam. Before final orders were passed, it was necessary for him to go to Simla, to explain matters in person to the Foreign Department. The programme sanctioned will, I trust, lead to a considerable increase of our knowledge of the hitherto unexplored regions bordering the Upper Assam Valley.

No. III.—TRIGONOMETRICAL.

THE SECONDARY TRIANGULATION IN BURMAH.

(18.) The state of these operations at the commencement of the season was as follows. Three series of secondary triangulation had been partially carried out, and stations had been chosen for part of a fourth. These were—(1) the series from Myanong to Cape Negrais; (2) the one from Prome to Thayetmyo and Tonghu; (3) the one from Rangoon along the coast, westwards; and (4) a chain of triangulation nearly on the meridian of Tonghu, intended to meet the second of the above in the neighbourhood of Tonghu.

PERSONNEL.

Mr. W. G. Beverley, Officiating Assistant Superintendent, 1st Grade.
" J. Low, Surveyor, 2nd Grade.
" J. W. Mitchell, Surveyor, 4th Grade.
" D. J. Collins, Assistant Surveyor, 4th Grade.

(19.) These secondary chains of triangles all emanate from the principal triangulation of the Eastern Frontier Series, and were projected with the following objects. No. 1 to fix the position of Cape Negrais and the Alguada lighthouse, while it would enable the town of Henzada, and the civil station of Bassein near which it passes, to be laid down. It was carried forward 36 miles in a direct line during the season, through a very difficult country, leaving about 80 miles remaining to be done. No. 2 is to determine the positions of the stations of Prome, Thayetmyo, and Tonghu; besides which, it will, when completed in conjunction with No. 4, fill-in a bend of the frontier which the main triangulation could not follow. Early in March it had been nearly completed for a distance of about 44 miles by Mr. Low; while of the fourth, about 56 miles were completed by Mr. Mitchell, some of the stations visited by the latter having been previously chosen. There then remained a gap of only about 50 miles between the two, which Mr. Beverley considered could be completed by Mr. Low during the rest of the season, so he recalled Mr. Mitchell for work elsewhere. Unfortunately Mr. Low just at that time fell sick, and was obliged to take leave of absence; and, although he returned to duty after a few weeks' absence, he was unable to do much more triangulation, and consequently the gap still remains to be filled up. The 3rd series is intended to determine the position of the Krishna Shoal light; but, through various causes, this was not carried out, which is perhaps the less to be regretted as, during the monsoon succeeding the field-season, that light was destroyed, and it is highly improbable that the new one which is intended to be built will be in exactly the same position. About 70 miles of this triangulation remains to be done.

(20.) The operations generally were carried on through most difficult country, the hills met with being flat-topped, densely wooded, and without any

characteristic features to distinguish one from another. The difficulty of obtaining labourers was also very great, as the country is sparsely inhabited, and the Burmese coolies object strongly to being absent from home for more than a day or two. Each of the officers of the party suffered much in health. The postal communications were very irregular and unsatisfactory. The out-turn of work was much affected by these causes, and falls short of the average; but the surveyors appear to have worked zealously and well. It would perhaps have been more judicious on the part of Mr. W. G. Beverley, who was in command, to have secured the completion of Messrs. Low and Mitchell's triangulation before removing the latter; but he could not have foreseen Mr. Low's illness, which upset his arrangements.

(21.) On 18th May, Mr. W. G. Beverley obtained furlough for eight months, and the charge of the party was made over to Mr. H. Beverley, by whom the recess duties were carried on, and the report for the year was submitted.

No. IV.—TRIGONOMETRICAL.

THE EASTERN FRONTIER SERIES, MOULMEIN.

PERSONNEL.

Captain J. Hill, R.E., Assistant Superintendent, 1st Grade.
Mr. H. Beverley, Surveyor, 1st Grade.
„ J. C. Clancy, Assistant Surveyor, 3rd Grade.
„ J. O. Hughes, „ „ „

(22.) On the retirement of Mr. Rossenrode, which took place on the 1st November 1876, as was duly noticed in the last report, the charge of the series was temporarily entrusted to Mr. H. Beverley, pending the arrival of Captain J. Hill, R.E., on his return from furlough. Captain Hill did not reach the party until the 16th March; consequently all the arrangements for the field-season, and nearly all the actual operations, were carried out by Mr. H. Beverley, and under his orders; indeed, the programme of the season was so nearly completed when Captain Hill joined, that he judged it best to allow Mr. Beverley to finish the principal triangulation.

(23.) The out-turn of the season comprises the completion of a compound figure round Yebudoung H. S., which was partly observed during the preceding season, and the execution of one hexagon and two quadrilaterals in continuation to the south, bringing the triangulation down to the parallel of 14° in latitude. Twelve stations were visited, affording 17 triangles which cover an aggregate area of 2,032 square miles, and carry the series forward over a distance of 92 miles. The approximate series was carried 56 miles, leaving a hexagon in advance of the completed principal triangulation in readiness for next season's opening observations. As regards secondary triangulation, the state of the atmosphere prevented the determination of "The Three Pagodas" an important boundary-mark between Siam and Tenasserim –which is to be regretted. The town of Yeh, and two others, being the only ones of any importance which were met with, were laid down.

(24.) The country is a difficult one to triangulate, being forest-clad, almost destitute of roads, and very thinly populated. Many miles of pathway had to be cut by the men of the establishment, and long detours were sometimes necessary between stations; for instance, in one case a direct distance of 18 miles necessitated a circuitous march of 80 miles. The sparseness of population necessitated special arrangements to secure instrument-carriers and labourers, and also to provide food for the establishment. Mr. Beverley appears to have shown good judgment in his arrangements, and energy in the execution of his work; and the results do him much credit.

(25.) The operations of the field-season were brought to a close under Captain Hill's directions, on the 24th April, when the party left Tavoy and proceeded to Moulmein for recess quarters. The party was fortunate in being nearly free from sickness throughout the season, although cholera and small-pox were prevalent in some of the villages visited.

(26.) This triangulation has now reached the parallel of Bangkok, the capital of Siam, and a chain of triangles of little more than 100 miles in length will suffice to connect that important city with the triangulation of India. The

distance from Tavoy to Bangkok by sea being over 2,000 miles, it is obvious that a direct trigonometrical connection will be of great value to check and rectify the Marine Surveys which have been carried along the coast-lines. The Government of Siam has therefore been invited to allow of the execution of the proposed chain of triangles.

No. V.—TRIGONOMETRICAL.

THE EASTERN SIND SERIES, MERIDAN 70°.

(27.) It was stated in the last report that Captain Rogers, having completed the Jodhpur Series on the meridian of 72½°, took up the Eastern Sind Series, 2½° of longitude to the west, and prepared a large number of principal stations for the final observations. In the season now under review, these observations have been completed at 28 stations, affording 32 triangles arranged in six figures, *viz.*, four hexagons and two quadrilaterals. The series has been carried forward over a distance of 125 miles on the prescribed meridian, and embraces an area of 2,455 square miles. Stations have also been chosen and prepared for a distance of 98 miles in advance of the final observations. The nature of the country does not give much scope for secondary triangulation; but this part of the work was not neglected, and the positions of a number of revenue survey stations and boundary-pillars were determined. Captain Rogers worked energetically and well, and he reports that he was well seconded by his assistants.

Personnel.

Captain M. W. Rogers, R.E., Officiating Deputy Superintendent, 3rd Grade.
Mr. W. C. Price, Surveyor, 4th Grade.
„ C. P. Torrens, Assistant Surveyor, 3rd Grade.
„ P. F. Prunty, „ „ 4th „

(28.) The country passed through was generally a desert, of a worse description than that met with in former seasons on the Jodhpur Series, which has been described in former reports. It is composed for the most part of parallel ridges of sand, of considerable height, and with steep slopes covered with low thorn-jungle. Marching through such country, when the direction of the march can be in no way altered to suit the lie of the sandhills, is most tedious work. Captain Rogers describes the curious formations, known as "Draens," which occasionally occur in this desert. These are tracts of many miles in extent, where the regular sandhills disappear, and give place to a variously-moulded surface of continually-shifting sand, utterly devoid of vegetation. These draens are seldom crossed by the natives, and when the survey-party was forced to cross one, careful preparations had to be made in the first instance, and the progress was very slow, five miles proving to be a fatiguing march. It is a remarkable fact that occasionally wells are found in small patches of hard soil in the midst of these wastes of sand, and that the water in such wells is invariably good, though everywhere else it is scarcely drinkable. In fact, to obtain potable water in this region is a constant difficulty, one district of about 30 by 40 miles being reported as altogether without that necessary of life.

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No. VI.—TOPOGRAPHICAL.

THE SURVEY OF KATTYWAR.

(29.) Major Pullan has been carrying on this survey, but with a smaller staff of assistants than he had last year, which has necessarily reduced his out-turn of work as compared with the previous season. This will be seen by the following figures:—

Personnel.

Major A. Pullan, S.C., Officiating Deputy Superintendent, 3rd Grade.
J. McGill, Esq., Officiating Assistant Superintendent, 1st Grade.
Mr. F. Bell, Surveyor, 3rd Grade.
„ N. C. Gwynne, Surveyor, 4th Grade.
„ W. A. Fielding, Assistant Surveyor, 2nd Grade.
„ G. T. Hall, „ „ 3rd „
„ H. Corkery, „ „ 4th „
„ J. Keating, „ „ 4th „
Visaji Ragonath Gadboli, Head Sub-Surveyor; and
Ten other Sub-Surveyors.

	Season 1875-76.	Season 1876-77.	
Topographical ...	2,253	1,716	square miles.
Trigonometrical .	1,850	2,062	„ „
Traverse ...	1,600	752	linear „

(30.) The operations this year were carried on in portions of the Hallar and South divisions of Western Kattywar. The principal towns which come within the area of country surveyed are—in sheet 46, Bhayawadar, Jodhpur, and Dhank; in sheet 47, Upleta, Dhoraji, and Kuntiyana; in sheet 48, Bantwa and Wanthali; and in sheet 50, Viráwal and Patan, which last is remarkable for the ancient and world-known Hindu temple of Somnath, now said to be fast falling to pieces, and requiring some steps to be taken to arrest the progress of decay. The country is generally thickly populated; and it is well watered by several rivers, of which the most noticeable are the Moz, the Bhadar, the Uben, the Harna, and the Ojat—the last a deep stream, which, after pursuing a tortuous course to the west, falls into the Bhadar river close to its mouth at Navi Bandar, on the shore of the Gulf of Cutch.

(31.) During the recess season of 1876, fair maps of four sheets were prepared, each in four sections, on the scale of two inches to a mile, for reduction and publication on the one-inch scale. Reductions of eighteen sheets surveyed in previous seasons were prepared, on the scale of one quarter inch to the mile, for incorporation into the Atlas of India. The out-turn of work of all kinds, both in the field and during the recess, is very creditable to Major Pullan, who was well seconded as usual by Mr. McGill.

(32.) Steps will be taken during the field season which is now progressing to extend the triangulation into Cutch with the view of commencing the topographical survey of that Province.

No. VII.—TOPOGRAPHICAL.

THE SURVEY OF GUZERAT.

(33). Lieutenant-Colonel Haig, R.E., supervised the field operations of this survey until about the middle of March, and then proceeded to Europe on furlough, making over the charge of the party to his Assistant, Lieutenant Gibbs, R.E., by whom the general operations were supervised during the remainder of the field-season and the commencement of the recess. On the 13th June, Captain Carter, R.E., took over the charge from Lieutenant Gibbs, and he has retained it up to the present time.

PERSONNEL.

Lieutenant-Colonel C. T. Haig, R.E., Deputy Superintendent, 2nd Grade.
Captain T. T. Carter, R.E., Deputy Superintendent, 3rd Grade.
Lieutenant J. E. Gibbs, R.E., Officiating Assistant Superintendent, 2nd Grade.

Mr. A. D'Souza,	Surveyor,	1st	Grade.
„ A. Christie,	„	4th	„
„ C. H. McA. Fee,	„	„	„
„ J. Hickie, Assistant	„	2nd	„
„ G. D. Cusson,	„	„	„
„ S. F. Norman,	„	4th	„
„ C. Norman,	„	„	„

SUB-SURVEYORS.

Mr. Ferns,
„ George,
Gopal Vishnu,
and
Eighteen Native Sub-Surveyors and Apprentices.

(34.) The out-turn of the work of all descriptions has been very satisfactory. An area of 1,988 square miles was surveyed topographically on the scale of two inches to the mile, the British districts in minute detail for publication on the same scale, the Native States in less detail for publication on the one-inch scale. This area falls in sheets Nos. 15, 28, 29, and 30 of the survey (see the Index chart, opposite page of the Appendix), and is sub-divided between British districts and Native States in the following proportions:—

BRITISH	Kaira Collectorate	342	square miles.
	Surat „	204	„
	Panch Máhals	83	„
NATIVE	Baroda	1,202	„
	Sachin	32	„
	Rewakánta	125	„

The area which was triangulated and traversed in advance for future topography consists of 2,200 square miles, appertaining to sheets Nos. 6, 7, 26 and 27; and 280 square miles for the survey of the forests of the Dangs, sheet 52.

(35.) The following maps were drawn and sent in for publication, *viz.*—three of the sections of sheet 78 and as many of sheet 79, drawn for reproduction on the two-inch scale; and the four sections of each of the following sheets—Nos. 30, 78, 79, 80, 81, and 82, drawn for reduction to the one-inch scale. In addition to this, sections 10 and 12 of sheet 14, on the four-inch scale, were entirely re-drawn, as the maps first drawn were found to be unsuited for photo-zincography; and the proofs of 15 sections of the four-inch survey were examined and corrected after photo-zincography.

(36.) Two of Eckhold's omnimeters, manufactured by Messrs. Elliott Brothers, were employed in running traverses through the Dang forests. These instruments are theodolites which are furnished with an auxiliary appliance for enabling the vertical angle subtended by any object to be measured with great accuracy, whereby, when the height of the object is known, its distance may be readily determined. The usual object is a pole, the exact length of which has been carefully ascertained in the first instance. With the omnimeter and its subtense pole, distances of several hundred yards may be measured over rugged and broken ground, where it would be very difficult or impossible to employ a chain, with a degree of accuracy not materially less than that with which the same distances may be measured over smooth ground with the usual measuring-chains. Besides which, one and the same set of readings to the subtense pole enables both the altitude, and the horizontal distance of the point on which the pole is set up, to be readily determined, with a sufficient degree of accuracy for most practical purposes, provided that the distance between the instrument and the pole does not materially exceed a mile. As theodolites, these instruments were found to be very inferior to those of the same sizes which are ordinarily employed in the operations of this Survey; but for the special purposes for which they were required, they gave better results than had been expected, and they are certainly very useful instruments for carrying a line of traverse over a difficult country where chaining is impossible.

(37.) An interesting account of the chief towns and rivers falling within the area of the year's operations will be found in Lieutenant Gibb's report, at page 21—a of the Appendix. And I may here observe that the annual reports for 1873-74 and 1874-75 contain valuable papers by that officer on the portions of the Dangs in which he had been operating. This year he had collected rock specimens for the purpose of determining the petrology of portions of the district, and was preparing additional notes on the botany, to be added to in the following year and then published.

(38.) But I grieve to state that, on returning to resume operations at the commencement of the field-season of 1877-78, Lieutenant Gibbs was attacked with cholera, when encamped at a place in the Ahmedabad district, far from medical assistance of any kind; being unconscious of his critical condition, he would not allow his servants to send for the nearest doctor, nor even to inform his friend, Mr. LeMessurier, who was encamped a few miles off, until it was too late. He died on the morning of the 21st November 1877. Though the youngest, he was one of the finest and most valuable of the officers of this Department. Gifted with rare abilities, and with the capacity of turning those abilities to good advantage, full of ardour in the prosecution of his own work, and most willing and anxious to assist others in every way, his death is as much to be regretted in the interests of the public service, and more particularly of this Department where he was so highly appreciated, as it is mourned in the circle of his family and friends.

(39.) Of the nature of the country operated in, Lieutenant-Colonel Haig states in his report (not printed) that, "with the exception of the southern portion of sheet 30, the whole of the country under final survey this season has been thickly wooded and much intersected with tortuous and precipitous ravines and water-courses. This has made the progress slow, though all the European assistants have worked well." Of the mapping, Captain Carter states that "a considerable portion of the drawing of the maps for reproduction [to full scale] is done by Mr. T. A. LeMessurier, who is in charge of the party of the Guzerat Revenue Survey which is attached to this office, with a view to our utilizing the detail shown on the village maps by transferring the same to our two-inch maps of British territory. The surveyor's duty in the field-season is to fix by traverse the tribeta or boundary-marks where three villages meet. These points are

then plotted on our plane-tables, and the village boundaries are transferred to the plane-table by proportional compasses adjusted to the tribetas. This work is done by the Revenue Survey establishment on return to Head Quarters. We are fortunate in having an officer of Mr. LeMessurier's acquirements and drawing abilities, who is thus a great help in turning out the fair maps on which we show the details taken from the Revenue Survey."

No. VIII.—TOPOGRAPHICAL.

THE SURVEY OF KUMAON AND GARHWAL.

(40.) After the field-operations of this survey during the season 1874-75 had been completed, only a small area remained to be done, lying at the extreme north-east end of the district. It was thought best to leave the survey in abeyance during the season of 1875-76, with a view to applying the whole strength of the party to the survey of the Dehra Dún district, which was by these means completed in that season. The survey of Kumaon and Garhwál was resumed this year under charge of Mr. E. C. Ryall with the staff detailed in the margin, and I have much satisfaction in being able to report that the whole of the field-work is now complete.

PERSONNEL.

E. C. Ryall, Esq., Officiating Assistant Superintendent, 2nd Grade.
Mr. J. Peyton, Surveyor, 1st Grade.
" W. Todd, " 2nd "
" T. Kinney, Assistant Surveyor, 1st Grade.
" J. Pocock, " " 3rd "
" R. F. Warwick, " " 4th "
and
Six Native Surveyors.

(41.) The field-party consisted of Messrs. Ryall, Peyton, Pocock, and Warwick, and two native sub-surveyors, Mr. Todd remaining at Head Quarters, Dehra Dún, in charge of the mapping office, where he was temporarily assisted by Mr. T. Kinney. Mr. Ryall and party left Almorah for the scene of their work about the middle of April.

(42.) The winter of 1876-77 is reported to have been exceptionally severe in these regions; and the spring and early summer of 1877, up to as late as June, were unusually cold and wet. The start from Almorah, long delayed by heavy rain, was eventually made in fine weather, which proved only a break in the wet, as the rain began again on 17th April and lasted till 8th June. Such weather was very much against the surveyors, the field of whose operations had an average elevation of about 16,000 feet above sea-level, and occasionally rose much higher; thus Mr. Ryall's highest point of observation was 19,600, while Mr. Pocock executed one plane-table section at an average elevation of 19,000 feet. The snow-line was found to be much lower than usual, and the inhabitants of the upper valleys, who move up to the higher pastures during each summer, were detained in their winter homes long beyond the ordinary time. As the surveyors depend on these people for the greater part of their supplies, it was impossible to proceed with the work until they could be persuaded to move, and some delay was experienced on this account. Thus Mr. Ryall did not succeed in getting over the Untar Dhurra pass, which has an elevation of 17,350 feet, until the 3rd June.

(43.) On the 8th Mr. Ryall reached Hundes, a district of Chinese Thibet lying north of Kumaon and Garhwál. He hoped that his arrival before the passes were fairly open would be unnoticed, and would enable him to reach the bank of the Sutlej river, which he proposed to survey along, back to his base in British territory, before the jealousy of European intruders entertained by the natives should interfere with his movements. He was disappointed in the hope of his arrival being unnoticed, as he was met at the very boundary by two natives, who immediately proceeded to report the fact to the officials of the district. Mr. Ryall, however, was fortunate in being able to give reasons for crossing the boundary which were deemed sufficient, so he was permitted to go on with his work. After doing all he could in Hundes, he hastened back to form a connection between the work there and the base on the Unta Dhurra ridge, as well as to observe the third angle at some of the stations in the Milam Valley, which, owing to heavy rain and other causes, had been left unobserved in 1874. When he had done this, he finished the topography of this valley, the entrance

into which, through a stupendous gorge about 12 miles in length, overhung by large masses of granite precipices, is described as most formidable. The road consists for the most part of a series of narrow steps built along the faces of steep hillsides or rugged precipices; and, in other parts where this is impracticable, planks leading from one ledge to another are laid across.

(14.) Mr. Peyton was entrusted with the survey of the Byans Valley, which he completed satisfactorily; some notes on his work and the topography of the valley will be found embodied in Mr. Ryall's report. At Garbia, the largest village in the valley, Mr. Peyton noticed that the Tartar physiognomy by no means predominated, and, although the noses were generally somewhat broad and the cheek-bones large and prominent, yet he saw some faces which in any country would be acknowledged to be pretty and expressive.

(15.) The total out-turn of work reflects much credit on Mr. Ryall and his assistants, considering the nature of the ground surveyed. An area of 870 square miles was triangulated for topography, and areas of 959 and of 640 square miles were sketched topographically on the respective scales of half an inch and one inch to the mile. Besides this, a larger number of peaks were fixed in an area of about 13,000 square miles of territory beyond the British frontier, which will be of great value in rectifying and amplifying the existing sketch maps of that region; the additional geographical information thus acquired will, I trust, form the subject of a future Trans-Himalayan exploration report from the pen of Mr. Ryall.

(16.) Mr. Ryall was supplied with four of the new portable mercurial barometers designed by Captain St. George. These barometers have arrangements whereby the tubes can be readily filled with mercury without any considerable admixture of air, so that a practically perfect vacuum may be obtained whenever desired; the tubes are intended to be emptied whenever the instrument has to be transported about, and thus the risk of breakage is very much less than for a barometer carried about, as usual, with its tube full of mercury. The instruments were filled and read at various heights, ranging from 11,000 to 19,000 feet, which had been independently determined by the triangulation; the differential barometric determinations agreed fairly with the trigonometrical as a rule, though there are some startling differences which have not yet been accounted for; the absolute heights were far more frequently in defect than in excess, which tends to show that little air can have got into the tubes during the process of filling them with mercury, and is so far satisfactory. The process of filling is, however, a tedious one, and difficult to accomplish when the fingers are chilled at very high altitudes; but the barometers are strong and portable, and, with moderate care, they may be carried over the most rugged mountain regions without much fear of breakage.

(17.) The operations of the present year have completed the topographical survey of Kumaon and Garhwál, which is a matter of much gratification.

No. IX.—SPIRIT-LEVELLING.

OPERATIONS IN GUZERAT.

(48.) These operations are under the charge of Captain Baird, R.E., and during season 1875-76 two parties were employed, one directly under Captain Baird himself, and the other under Mr. Rendell. At the end of that field-season, Captain Baird went to England on three months' privilege leave, and was afterwards detained there on duty in connection with the reduction of the tidal observations in the Gulf of Cutch which had been made in the previous year. The levelling operations now under report were consequently confined to one party under Mr. Rendell, working on instructions drawn up by Captain Baird before proceeding on leave.

PERSONNEL.

Captain A. Baird, R.E., Officiating Assistant Superintendent, 1st Grade.
Mr. T. H. Rendell, Assistant Surveyor, 1st Grade.
Narsing Dass, Sub-Surveyor.

(49.) They comprise 358½ miles, carried out on the usual rigorous system of this Department, by two observers working independently and checking each

other station by station. Of this, 183½ miles was a part of the main line between the Gulf of Cutch and Bombay, commencing a little below Ahmedabad and running south through Broach and Surat down to Damaun railway station, where it was closed for the season. The remaining 171¾ miles are distributed in branch lines connecting important places *en route*, such as Cambay, and places along the railway of His Highness the Guicowar to Dabhei, and along the branch line of the Bombay, Baroda, and Central India Railway from Anand to Pali.

(50.) The heights of 306 permanent bench-marks were determined, several of which were also points of the Railway and the Irrigation systems of levelling, which have thus been connected together and referred to the same datum as that of the Survey Department. The value of such checks is proved by several cases of discrepancy which were discovered by Captain Baird. The out-turn of work is satisfactory, both as respects quantity and quality, and is very creditable to Mr. Rendell.

No. X.—TIDAL INVESTIGATIONS.

ANALYSIS OF OBSERVATIONS AT TIDAL STATIONS IN THE GULF OF CUTCH AND AT TUTICORIN.

(51.) In previous reports I have given the history of these operations, and described the several steps which have been taken in order to obtain continuous registers of the momentarily varying changes in the sea-level, at the points on the coasts of the Gulf of Cutch, and at Tuticorin, where tidal stations had been erected. The observations also included continuous registers of the barometric pressure, and of the velocity and direction of the wind, which were taken by self-recording instruments at each station *pari passu* with the tidal registers. When all the observations were completed, the ordinates of the several curves were measured, (taking full account of clock error whenever there was any) and then tabulated for each hour of every day. The numerical results thus obtained serve as the data on which the analysis of the observations was subsequently based.

(52.) This analysis, I felt assured, would be best performed with the assistance and co-operation of Mr. Roberts, of the Nautical Almanac Office in London, by whom all the tidal observations taken for the British Association had been, and are still being, reduced and analyzed, under the superintendence of Sir William Thomson. I therefore obtained sanction for Captain Baird to remain in England, and reduce his observations with Mr. Roberts' assistance. The results will be presently stated. But first it is necessary to give a brief epitome of the method of investigation which has been followed, and which is described in detail in the notes on the Harmonic Analysis of Tidal Observations, London, 1872, and in various numbers of the proceedings of the British Association.

(53.) The rise and fall of the level of the ocean, twice, or nearly so, in twenty-four hours, is well known to be due to the attractions of the sun and the moon. If the orbit of the earth and that of the moon were quite circular and lay in the plane of the equator, and if the moon performed its revolution round the earth in the same time that the sun appears to revolve around the earth, then there would be two tides daily, differing from each other in form—should the sun and moon not be in conjunction—but recurring alike from day to day. The moon, however, makes her circuit of the earth in 18 minutes over the twenty-four hours and thus the sun makes thirty apparent circuits of the earth while the moon is only making twenty-nine; moreover, the orbits of the earth and of the moon are not circular, nor are they situated in the plane of the equator. Thus the positions of the sun and moon, relatively to the earth, are momentarily varying in distance, declination, and right ascension. Consequently, the level of the ocean is subject to momentary variations in the dynamical action of the disturbing bodies; and these cause a variety of tides which recur periodically, some in short, others in long, periods.

(54.) In the present investigations, the short and the long period tides have been analyzed by different methods. The former—which here embrace all tides recurring in periods of or about a day in duration, and in any aliquot part of the *quasi*-diurnal period—have been treated in accordance with the synthesis

of Laplace. Thus a number of fictitious stars are assumed to move, each uniformly in the plane of the earth's equator, with angular velocities which are small in comparison with that of the earth's rotation, so that the period of each is something not very different from 24 mean solar hours. Each star is supposed to produce a primary tide in its *quasi*-diurnal period, and also various sub-tides which run through their periods respectively twice, three times, or oftener during the primary period; some of the stars, however, do not produce a full-period tide, but only sub-tides in the sub-periods.

(55.) The portion of the height of the sea-level above or below its mean height (with reference to some fixed datum line), which is due to the combined influences of the several tides produced by any one of the fictitious stars, is given by the following well-known expression of the law of periodicity:—

$$h = R_1 \cos(nt - \epsilon_1) + R_2 \cos(2nt - \epsilon_2) + R_3 \cos(3nt - \epsilon_3) + \ldots$$

in which h is the height above mean sea at any moment, t is the time expressed in mean solar hours, commencing at 0^h astronomical reckoning, and n is the angular velocity of the star in degrees of arc per mean solar hour, so that $360^\circ \div n$ denotes the period of the star in hours of mean time. R_1 is the amplitude, and ϵ_1 the epoch of the full-period tide; R_2 and ϵ_2, R_3 and ϵ_3, &c., are the amplitudes and epochs of the sub-tides, whose periods are one-half, one-third, &c., that of the primary period. The amplitude is the semi-diameter of the circle whose circumference indicates the path of a tide. The epoch is the arc which, when divided by the angular velocity of the tide, gives the hour angle when the height of the tide is a maximum; this occurs, on the day of starting, when $nt = \epsilon_1$ for a primary tide, when $2nt = \epsilon_2$ (and again 12 *quasi*-hours afterwards) for a tide whose period is half that of the primary, and so on.

(56.) Thus, if we now put h for the height of the sea-level at any moment, and A for the value of the height of the mean sea-level which results from the combined influnce of the whole of the fictitious stars, we have—

$$h = A + \Sigma \{R_1 \cos(nt - \epsilon_1) + R_2 \cos(2nt - \epsilon_2) + \ldots\}$$

where the symbol Σ stands for the summation of the whole of the terms within the brackets which relate to all the fictitious stars.

(57.) There are two principal stars, respectively called S and M for brevity, the first of which represents the mean sun, or that point in the plane of the earth's equator whose hour-angle is equal to mean solar time; the second represents the mean moon, a point moving in the plane of the equator with an angular velocity equal to the mean angular velocity of the moon. The other fictitious stars respectively furnish the corrections to S and M for declination and parallax, to M for lunar evection and variation, and to S and M for the compound actions which produce what are called Helmholtz Tides, &c. The 24th part of the period of star S being an hour, that of any other of the fictitious stars may be conveniently spoken of, and is here called a *quasi*-hour.

(58.) To find the argument (the angular velocity n of the preceding formulæ) for each fictitious star, various combinations have to be made of the following fundamental angular velocities, *viz.* :—

γ, the earth's rotation	$= 15^\circ{\cdot}0410686$	per mean solar hour.	
σ, the moon's revolution round the earth ...	$0{\cdot}5490165$	,,	,,
μ, the earth's revolution round the sun ..	$= 0{\cdot}0410686$	,,	,,
$\tilde{\omega}$, the progression of the moon's perigee ..	$= 0{\cdot}0046418$	,,	,,

The several fictitious stars whose tides have been analyzed in these investigations are—

S, with argument	$n = \gamma - \eta$		$= 15^\circ$
M	,,	$\gamma - \sigma$	$= 14{\cdot}4920521$
K	,,	γ	$= 15{\cdot}0410686$
O	,,	$\gamma - 2\sigma$	$13{\cdot}9430356$
P	,,	$\gamma - 2\eta$	$14{\cdot}9589314$
J	,,	$\gamma + \sigma - \tilde{\omega}$	$= 15{\cdot}5854433$
Q	,,	$\gamma - 3\sigma + \tilde{\omega}$	$= 13{\cdot}3986609$
μ	,,	$\gamma - 2\sigma + \eta$	$= 13{\cdot}9841042$
N	,,	$\gamma - \frac{1}{2}\sigma + \frac{1}{2}\tilde{\omega}$	$= 14{\cdot}2198648$
L	,,	$\gamma - \frac{1}{2}\sigma - \frac{1}{2}\tilde{\omega}$	$= 14{\cdot}7642394$
ν	,,	$\gamma - \frac{1}{2}\sigma - \frac{1}{2}\tilde{\omega} + \eta$	$14{\cdot}2562915$
λ	,,	$\gamma - \frac{1}{2}\sigma + \frac{1}{2}\tilde{\omega} - \eta$	$14{\cdot}7278127$
MS	,,	$\gamma - \frac{1}{2}\sigma - \frac{1}{2}\eta$	$14{\cdot}7460261$
and SM	,,	$\gamma + \sigma - 2\eta$	$= 15{\cdot}5079479$

(59.) The *quasi*-hour angles of the several fictitious stars, other than S, at mean noon of the day of starting, were found by putting

$\gamma =$ the Sidereal time,
$\eta =$ the Sun's mean longitude $= \gamma$,
$\sigma =$ the Moon's mean longitude,
$\sigma - \bar{\omega} =$ the Moon's mean anomaly,

and taking the corresponding numerical values of each element for the hour and station from the Nautical Almanac and Hansen's Lunar Tables, and then substituting these values in the preceding symbolic expressions for the hourly variations of the several stars.

(60.) The number of stars and the angular velocity of each star having thus been decided on, *a priori*, from theoretical considerations, the values of the constants R and ε for the tidal constituents of each star have to be determined from the evidence afforded by the tabulated values of the height of the sea-level for every hour of the day during the entire period of observation, which should not be less than 371 days. The values of the constants have been computed for the several tides at the three stations of Okha, Nowanár, and Hanstal, and are given below. It will be remembered (see Section XI of my Report for 1874-75) that Okha is situated at the entrance to the Gulf of Cutch, Nowanár midway up the Gulf, and Hanstal at its upper extremity; also that continuous observations over a period of not less than 14 months were obtained at the upper and lower stations, whereas at the middle station, Nowanár, there was a break of several months, in consequence of an alteration of the foreshore during the monsoon of 1874; thus the results for Nowanár are far from being as exact and complete as those for the two other stations.

Table of the Constants.

	Okha.	Nowanár.	Hanstal.
	Feet. °	Feet. °	Feet. °
The star S ...	$R_1 = 0{\cdot}0741, \varepsilon_1 = 149{\cdot}89$	Wanting.	$R_1 = 0{\cdot}1292, \varepsilon_1 = 164{\cdot}01$
	$R_2 = 1{\cdot}2224, \varepsilon_2 = 14{\cdot}37$	$R_2 = 1{\cdot}8933, \varepsilon_2 = 55{\cdot}33$	$R_2 = 1{\cdot}9277, \varepsilon_2 = 84{\cdot}51$
	$R_4 = 0{\cdot}0132, \varepsilon_4 = 116{\cdot}57$	$R_4 = 0{\cdot}0131, \varepsilon_4 = 359{\cdot}56$	$R_4 = 0{\cdot}0211, \varepsilon_4 = 61{\cdot}74$
	$R_6 = 0{\cdot}0030, \varepsilon_6 = 20{\cdot}92$	Wanting.	$R_6 = 0{\cdot}0069, \varepsilon_6 = 166{\cdot}57$
	$R_8 = 0{\cdot}0006, \varepsilon_8 = 219{\cdot}81$	Ditto.	$R_8 = 0{\cdot}0025, \varepsilon_8 = 158{\cdot}63$
The star M ...	$R_1 = 0{\cdot}1122, \varepsilon_1 = 120{\cdot}86$	Ditto.	$R_1 = 0{\cdot}1208, \varepsilon_1 = 155{\cdot}61$
	$R_2 = 3{\cdot}6936, \varepsilon_2 = 348{\cdot}08$	$R_2 = 5{\cdot}8448, \varepsilon_2 = 25{\cdot}32$	$R_2 = 6{\cdot}6291, \varepsilon_2 = 46{\cdot}52$
	$R_3 = 0{\cdot}0289, \varepsilon_3 = 22{\cdot}10$	Wanting.	$R_3 = 0{\cdot}0534, \varepsilon_3 = 93{\cdot}55$
	$R_4 = 0{\cdot}1265, \varepsilon_4 = 108{\cdot}88$	$R_4 = 0{\cdot}1023, \varepsilon_4 = 275{\cdot}00$	$R_4 = 0{\cdot}6803, \varepsilon_4 = 331{\cdot}55$
	$R_6 = 0{\cdot}0056, \varepsilon_6 = 272{\cdot}57$	Wanting.	$R_6 = 0{\cdot}2760, \varepsilon_6 = 248{\cdot}94$
	$R_8 = 0{\cdot}0102, \varepsilon_8 = 100{\cdot}06$	Ditto.	$R_8 = 0{\cdot}0726, \varepsilon_8 = 154{\cdot}36$
The star K ...	$R_1 = 1{\cdot}5605, \varepsilon_1 = 146{\cdot}60$	$R_1 = 1{\cdot}6857, \varepsilon_1 = 156{\cdot}00$	$R_1 = 1{\cdot}6502, \varepsilon_1 = 174{\cdot}60$
	$R_2 = 0{\cdot}4207, \varepsilon_2 = 24{\cdot}82$	$R_2 = 0{\cdot}4780, \varepsilon_2 = 76{\cdot}11$	$R_2 = 0{\cdot}6767, \varepsilon_2 = 88{\cdot}63$
The star O ...	$R_1 = 0{\cdot}8095, \varepsilon_1 = 322{\cdot}67$	$R_1 = 0{\cdot}7987, \varepsilon_1 = 332{\cdot}04$	$R_1 = 0{\cdot}8807, \varepsilon_1 = 340{\cdot}76$
The star P ...	$R_1 = 0{\cdot}3844, \varepsilon_1 = 319{\cdot}94$	$R_1 = 0{\cdot}2806, \varepsilon_1 = 342{\cdot}02$	$R_1 = 0{\cdot}3839, \varepsilon_1 = 353{\cdot}65$
The star J ...	$R_1 = 0{\cdot}1231, \varepsilon_1 = 176{\cdot}32$	$R_1 = 0{\cdot}1698, \varepsilon_1 = 191{\cdot}77$	$R_1 = 0{\cdot}1091, \varepsilon_1 = 222{\cdot}61$
The star Q ...	$R_1 = 0{\cdot}1596, \varepsilon_1 = 324{\cdot}68$	$R_1 = 0{\cdot}1697, \varepsilon_1 = 335{\cdot}14$	$R_1 = 0{\cdot}1618, \varepsilon_1 = 343{\cdot}23$
The star L ...	$R_2 = 0{\cdot}1511, \varepsilon_2 = 224{\cdot}77$	$R_2 = 0{\cdot}3569, \varepsilon_2 = 226{\cdot}93$	$R_2 = 0{\cdot}3892, \varepsilon_2 = 238{\cdot}32$
The star N ...	$R_2 = 0{\cdot}7551, \varepsilon_2 = 322{\cdot}94$	$R_2 = 1{\cdot}2205, \varepsilon_2 = 11{\cdot}72$	$R_2 = 1{\cdot}1535, \varepsilon = 26{\cdot}76$
The star λ ...	$R_2 = 0{\cdot}0712, \varepsilon_2 = 204{\cdot}40$	$R = 0{\cdot}1466, \varepsilon_2 = 251{\cdot}10$	$R^2 = 0{\cdot}2268, \varepsilon = 219{\cdot}57$
The star ν ...	$R_2 = 0{\cdot}1592, \varepsilon_2 = 8{\cdot}50$	$R = 0{\cdot}2975, \varepsilon_2 = 5{\cdot}43$	$R_2 = 0{\cdot}2864, \varepsilon_2 = 48{\cdot}24$
The star μ ...	$R_2 = 0{\cdot}1896, \varepsilon_2 = 184{\cdot}26$	$R = 0{\cdot}4026, \varepsilon_2 = 186{\cdot}44$	$R_2 = 0{\cdot}5569, \varepsilon = 179{\cdot}74$
The star SM ...	$R_2 = 0{\cdot}0435, \varepsilon_2 = 291{\cdot}24$	Wanting.	$R_2 = 0{\cdot}1309, \varepsilon_2 = 297{\cdot}74$
The star MS ...	$R_4 = 0{\cdot}0619, \varepsilon_4 = 112{\cdot}37$	Ditto.	$R_4 = 0{\cdot}3388, \varepsilon_4 = 13{\cdot}01$

(61.) It will be seen that the principal tides are first the *quasi*-semi-diurnal of M, and then the semi-diurnals of S and the *quasi*-diurnal of K, which range from one-third to one-fourth of the former. S and M being the principal stars, their sub-tides, down to the three hourly tide of S and the corresponding tide of M, have been computed. For K the *quasi*-diurnal and semi-diurnal tides were computed; for the stars O to Q only the primary tides. For the stars L to SM there are no primaries, and the tides of longest period are the *quasi*-semi-diurnal; for MS the longest tide is the *quasi*-demi-semi-diurnal; these, being the principal ones for each star, have been computed.

(62.) Here it is necessary to observe that the number of sub-tides which have to be investigated in each instance, in order to evaluate the full influence of the star, is a matter which can only be decided after considerable experience of such investigations has been gained by the analysis of the tides at a great variety of stations. It was therefore left to Mr. Roberts, whose practical familiarity with the subject probably exceeds that of any other individual, to prescribe the number of terms to be computed for each star.

(63.) On inserting the numerical values of the constants R and ϵ in the general expression, and substituting for nt its values in succession for every hour from the starting-point, the height (in feet) of each tide and sub-tide may be computed for every hour. The sum of these gives the portion of the height of the sea-level at that hour which is due to the influence of the short-period tides. This usually far exceeds the portion which is due to all other causes, and is thus frequently taken to represent the whole height.

(64.) Should it be desired to compute the hourly heights for any day of any year, without commencing at the starting-point of the observations, as may be necessary when tidal predictions are required, the values of γ, η, σ, and ϖ must be found, as in paragraph (59), for mean noon of the day which may be adopted as the new starting-point; the *quasi*-hour-angles of the several fictitious stars, other than S, at that moment must then be found, after which those for the succeeding hours may be obtained by successive additions of the respective hourly increments which are due to each star.

(65.) The values of the constants R and ϵ having been determined for each of the three tidal stations, the next step taken was the calculation of the height of the sea-level at each hour, throughout the entire period of registration at each station. The differences between the observed and the computed values were then taken as the data for calculating the influence of variations in barometric pressure, and in the velocity and direction of the wind, on the sea-level. Equations were formed in which the unknown quantities were B, the effect of a barometric pressure of one inch, and N and E, the effects of the North and the East components respectively of winds blowing at the rate of 10 miles an hour. Of these equations there were as many as the number of days of observation; they were solved by the method of minimum squares. Corrections were then computed for the daily variations of the atmospheric influences on the sea-level, and were applied to the values of height resulting from the previous investigations of the short-period tides. Finally, the differences between the heights thus determined and those actually observed were taken as the data for calculating the influence of each of the long-period tides.

(66.) The evaluation of the atmospheric influences gave the following factors for changes of sea-level due to a barometric pressure of one inch, and to north and east winds travelling with a velocity of 10 miles per hour:—

	At Okha.	At Hanstal.
Barometric pressure	+ 0·356 feet	— 0·438 feet.
North Wind	— 0·191 „	— 0·262 „
East Wind	+ 0·161 „	+ 0·087 „

These results are not satisfactory; the height of the sea-level at Okha appears to increase with an increase of barometric pressure, which is scarcely possible. It happens that at this station the changes of pressure occurred, as a rule, simultaneously with the changes of wind; and thus it is impossible to determine the separate effect of each, otherwise than by some arbitrary method of treatment. The observations will therefore be again analyzed, with a view to ascertaining whether they may not be made to yield more consistent results. Meanwhile, the values of the atmospheric factors already obtained must be

considered to be only approximate, giving fairly accurate results when employed collectively but not individually.

(67.) Of the constants for the long-period tides the following values have been computed for the stations of Okha and Hanstal, after the elimination of atmospheric influences by employing the preliminary values of the factors which are given in the preceding paragraph. At Nowanár sufficient observations are not forthcoming for the evaluation of either the atmospheric or the long-period tides.

Long-period tides, and their Constants.

$(\sigma \quad \tilde{\omega})$	Lunar monthly elliptic tide,
$2\ \sigma$	Lunar fortnightly declinational tide,
$2\ (\sigma \quad \eta)$	Luni-solar synodic fortnightly tide,
η	Solar annual elliptic tide,
$2\ \eta$	Solar semi-annual declinational tide,

Okha.		Hanstal.	
Feet.	°		Feet. °
$R=0{\cdot}058$,	$\epsilon=311{\cdot}38$	$(\sigma-\tilde{\omega})$	$R=0{\cdot}107$, $\epsilon=$ 14·17
„ 0·070,	„ 52·73	$2\ \sigma$	„ 0·142, „ 45·74
„ 0·136,	„ 248·19	$2(\sigma-\eta)$	„ 0·163, „ 11·76
„ 0·162,	„ 3·11	η	„ 0·024, „ 195·32
„ 0·121,	„ 114·75	$2\ \eta$	„ 0·090, „ 156·38

(68.) The present appears to be a good opportunity for giving the tidal constituents which were calculated by Mr. Roberts for the Port of Tuticorin, from observations taken there in the year 1871-72, by Captain Branfill, with a self-registering tide-gauge similar to those employed in the Gulf of Cutch.

Short-period tides at Tuticorin, and their Constants.

		Feet. °		Feet. °
Star S	...	$R_1=0{\cdot}039$, $\epsilon_1=$ 108·78	Star P ...	$R_1=0{\cdot}064$, $\epsilon_1=$ 281·78
		$R_2=0{\cdot}420$, $\epsilon_2=$ 97·59	„ J ...	$R_1=0{\cdot}011$, ϵ_1 181·70
		$R_4=0{\cdot}073$, ϵ_4 226·65	„ K	$R_1=0{\cdot}274$, $\epsilon_1=132{\cdot}80$
		$R_6=0{\cdot}063$, $\epsilon_6=$ 51·31		$R_2=0{\cdot}143$, $\epsilon_2=116{\cdot}25$
		$R_3=0{\cdot}007$, $\epsilon_3=202{\cdot}75$	„ Q ...	$R_1=0{\cdot}032$, $\epsilon_1=359{\cdot}08$
Star M	...	$R_1=0{\cdot}006$, $\epsilon_1=234{\cdot}64$	„ L ...	$R_2=0{\cdot}030$, $\epsilon_2=242{\cdot}50$
		$R_2=0{\cdot}596$, $\epsilon_2=$ 55·81	„ N ...	R_2 0·072, ϵ_2 38·69
		R_3 0·015, $\epsilon_3=182{\cdot}86$	Star λ ...	R_2 0·019, $\epsilon_2=218{\cdot}15$
		$R_4=0{\cdot}022$, $\epsilon_4=192{\cdot}76$	„ ν ...	R_2 0·022, $\epsilon_2=$ 35·58
		R_6 0·010, ϵ_6 45·91	„ μ ...	R_2 0·016, ϵ_2 183·83
		$R_8=0{\cdot}004$, ϵ_8 319·74	„ 2SM ...	R_2 0·011, $\epsilon_2=246{\cdot}37$
Star O	...	$R_1=0{\cdot}112$, $\epsilon_1=314{\cdot}25$	„ MS ...	$R_1=0{\cdot}018$, $\epsilon_1=282{\cdot}99$

Long-period tides at Tuticorin, and their Constants.

		Feet. °
Lunar monthly	...	$R=0{\cdot}024$ $\epsilon=313{\cdot}15$
Lunar fortnightly	...	„ 0·065 „ 69·54
Luni-solar fortnightly	...	„ 0·016 „ 307·85
Solar annual	...	„ 0·309 „ 313·35
Solar semi-annual	...	„ 0·080 „ 87·50

Here there were no data for evaluating the atmospheric tides separately, and it is probable that the magnitude of the amplitude of the solar annual tide is in great measure due to atmospheric influences.

No. XI.—TIDAL INVESTIGATIONS.

PROGRAMME OF FUTURE OPERATIONS.

(69.) The following important orders on the systematic record of tidal observations at selected points on the Coasts of India, were issued by the Government of India in the Department of Revenue, Agriculture, and Commerce, under date 4th July 1877:—

The Governor General in Council observes that the great scientific advantages of a systematic record of tidal observations on Indian coasts have frequently been urged upon, and admitted by, the Government of India. Hitherto the efforts in the direction of such a record have been desultory and in many cases wanting in intelligent guidance and careful selection of the points where the observations should be recorded. Additional importance has recently been given to the subject by the institution of a Marine Survey Department, for whose operations accurate tidal observations are a necessity without which no permanent record of the changes of ground in the different harbours of the coast can be kept up.

2. The advantages to be expected from well-considered and carefully conducted observations of the tides are mainly the following:—

(1) They enable standards to be fixed for the purposes of survey.

(2) They afford data for the calculation of the rise and fall of the tides, and thus subserve the purposes of navigation.

(3) They are of scientific interest apart from their practical usefulness as stated above.

The first two of these advantages are of strictly local bearing: an accurate survey of a port is essential to the safety of the shipping frequenting it, and correct tide-tables are necessary for the convenience of navigators and for engineering purposes within the port itself.

3. The Governor General in Council is of opinion that, in view of these considerations, every port where a tide-gauge is set up should pay for its establishment and maintenance from port funds. The third object, the scientific results to be expected from the record, will be sufficiently provided for by the appointment by the Government of India of one of its own officers to supervise and control the local observations, and to arrange for their utilization to the utmost extent possible. The charges will thus be divided in a manner appropriate to the advantages to be secured.

4. His Excellency in Council accordingly resolves to entrust the general superintendence and control of tidal observations upon Indian coasts to Captain Baird, R.E., Deputy Superintendent in the Great Trigonometrical Survey Department, who will be guided in his operations by the orders and advice of the head of that Department. This will involve no new charge upon Imperial Funds, for Captain Baird has for some years past been engaged upon observations of this nature in the Gulf of Cutch and in reduction of the observations in England: the work is of a nature which properly falls within the scope of the operations of the Great Trigonometrical Survey; and the object of the present change is merely to provide for its extension and systematization under an undivided control. Captain Baird will thus remain a member of the Department, and his operations will form one of the subjects to be treated by the Superintendent in his annual report.

5. The first duty of the Superintendent will be to instruct Captain Baird to determine, in communication with the Governments of the maritime provinces, the points where observations should be carried out. The necessary gauges (where these do not already exist) will then have to be provided from port funds, and the establishments entertained under the sanction of the Local Governments. It will probably be most convenient that all Captain Baird's communications with the establishments in charge should pass through the Local Governments, but this point may be settled as may be found most expedient in practice.

(70.) In accordance with these orders, enquiries have been, and are being, made with a view to ascertain the ports at which it will be desirable to establish tidal stations. The suitability of a port for this purpose will depend, *first*, on a site being available thereat, on which a self-registering tide-gauge may be erected, so as to be either immediately over the sea, or connected by piping with the sea at some point where there is a depth of not less than 10 to 15 feet of water at the lowest tides; *secondly*, on the presence of a port officer, who will exercise a general supervision over the operations, and correct the clocks of the several self-registering instruments, whenever necessary, either by direct determinations of time, or by arranging to get the true time from the nearest telegraphic office; *thirdly*, on the feasibility of making arrangements for the periodical inspection of the instruments at intervals of not less than six months generally, and more frequently when no officer is resident on the spot to superintend the operations.

(71.) So far as has yet been ascertained, the ports which seem likely to answer all the required conditions are Aden, Kurrachee, Bombay, Carwar, Beypore, Paumben, Madras, Vizagapatam, Akyab, Rangoon, and Port Blair. The following ports are believed to be unsuitable: Surat, Mangalore, Canna-

nore, Cochin, Muttrun, Negapatam, Coconada, False Point, Diamond Harbour, Moulmein, and Mergui.

(72.) At Aden a self-registering tide-gauge was erected by the local officers about two years ago; but the registers have been taken in such an unsatisfactory manner that the results are not of the slightest use. Captain Baird is now arranging for the establishment of a tidal station there, with proper instruments, and trained men to take charge of them. At Kurrachee a tide-gauge, which was originally set up by Mr. Parkes, has been in work for several years, and has furnished the data from which tide-tables for the port have been computed annually by Mr. Parkes. In course of time the present gauge—the scale of which is very small—should be replaced by one of those which are used by Captain Baird, and an anemometer and a barometer (both self-registering) should be set up beside the gauge. But it is not desirable to interfere with the working of the present arrangements at Kurrachee until other ports, at which nothing is now being done in the way of tidal observations, are duly provided for. At Bombay, Carwar, and Madras, instruments are now being set up by Captain Baird.

No. XII.—GEODETIC.

ELECTRO-TELEGRAPHIC DETERMINATIONS OF DIFFERENCES OF LONGITUDE IN SOUTHERN INDIA, AND BETWEEN BOMBAY AND SUEZ.

(73.) Measurements of differential longitude, with the aid of the electric-telegraph, were commenced in Southern India in the year 1872-73, when the following arcs between stations of the Great Trigonometrical Survey were measured by Major Herschel and Captain Campbell :—

PERSONNEL.

Captain (now Major) W. M. Campbell, R.E., Officiating Deputy Superintendent, 2nd Grade.
" W. J. Heaviside, R.E., Deputy Superintendent, 3rd Grade.
Mr. C. J. Neuville, Surveyor, 2nd Grade.
" E. J. Connor, Assistant Surveyor, 1st Grade.
" J. Bond, " " "

(1) Madras—Bangalore
(2) Bangalore—Mangalore

They are fully described in my report for that year. Operations were then suspended for two years, and were resumed in 1875-76, when the following arcs were measured by Captains Campbell and Heaviside :—

(3) Hyderabad (Bolarum)—Bombay
(4) Bellary—Bombay
(5) Hyderabad—Bellary
(6) Madras—Hyderabad (Bolarum)
(7) Madras—Bellary
(8) Bangalore—Bellary

(74.) In the present year the following arcs have been measured by Captains Campbell and Heaviside :—

(9) Vizagapatam—Madras
(10) Vizagapatam—Bellary
(11) Mangalore—Bombay

Thus differential determinations of longitude have been completed on eleven arcs between points in Southern India which had already been connected together by the great triangulation, whereby a considerable amount of information has been obtained which is of much value for geodetic requirements.

(75.) When these operations were commenced, I determined that they should be carried on, at least for some time, with great caution, and in such a manner as to be self-verificatory, in order that some more satisfactory estimate might be formed of the magnitudes of the errors to which they are liable, than would be afforded by the theoretical probable errors of the observations. It was evident that the observations might be burthened with various errors—some possibly constant—in the determination of the local times, and also in the transmission of the signals between the stations, and that no estimate could be formed of either the absolute or the relative magnitudes of these errors, unless steps were taken to verify the results by independent processes of operation. The simplest arrangement appeared to be to select three trigonometrical stations, as A, B and C, at

nearly equal distances apart, on a telegraph line forming a circuit, and, after having measured the longitudinal arcs corresponding to A B and B C, to measure A C independently as a check on the two first arcs. This is the principle which has been adopted as far as was practicable. The stations have been chosen on the telegraph lines in such a manner as to throw a network of triangles over the face of the country. In a few cases the lines of telegraph run in tolerable proximity to the sides of the triangles thus formed, and furnish an independent line for each side; more frequently, however, a line runs through a triangle, sending off branches to the stations right and left; and it occasionally happens that the wire is wanting on one side, and the electrical connection is made by linking-up the wires on the two other sides. Here this is less of independency as regards the errors involved in the transmission of signals, but the local times are still determined independently, as on a true circuit, and it now appears that this is the point which it is of most importance to secure.

(76.) It had long been questioned whether the errors to which operations of this nature are liable were due in greater measure to the astronomical or to the electrical parts of the observations; but experience has now shown that when there is direct electrical communication between the stations, without the intervention of relays, as has always been the case in our operations, the aggregate of the errors in the signalling between the stations is immaterial in comparison with that of the errors in the determination of the local time by astronomical observations. (See paragraphs 12 and 22 of Captain Campbell's report in the Appendix.) Thus it has been ascertained that the two arcs first measured have suffered to some extent, and are not as valuable as those subsequently measured, because of a defect in the construction of one of the two transit instruments which were employed in the time determinations, and not because of any sensible imperfection in the electric arrangements. This defect, which was known at the time, though its exact locus could not be immediately discovered, was traced home and rectified before any of the subsequent arcs were measured. But even with astronomical instruments which have no sensible defects, the several errors which are liable to obtain in the determination of the times, more particularly those arising from the personal equations of the observers, are found to materially outweigh those which occur in the transmission and receipt of the signals on an uninterrupted line of telegraph.

(77.) With regard to the determination of personal equation, an interesting circumstance was discovered this year, *viz.*, that in observing transits of stars, Captain Campbell's equation, relatively to that of Captain Heaviside, varied according as the star appeared to cross the field of the telescope from right to left or from left to right. Thus the original equation for all stars during the previous year had been

$$C-H = +\overset{s.}{\cdot}064 \pm \overset{s.}{\cdot}006$$

which it became necessary to replace by two new equations, *viz.*—

$$C-H = +\overset{s.}{\cdot}102 \pm \overset{s.}{\cdot}009 \text{ for stars north of the zenith.}$$

$$C-H = +\overset{s.}{\cdot}041 \pm \overset{s.}{\cdot}003 \quad \text{,,} \quad \text{south} \quad \text{,,} \quad \text{,,}$$

The previous reductions were corrected accordingly, with the effect of bringing the results into still closer harmony than the original values, which are given at page 15 of the report for last year.

(78.) The following table gives the telegraphic and the trigonometrical differences of longitude on each of the arcs:—

	Telegraphic. A	Trigonometrical. B	B A.
	m. s.	m. s.	s.
(1) Madras—Bangalore	10 39·04	10 39·61	+ 0·57
(2) Bangalore—Mangalore	10 56·77	10 57·17	+ 0·40
(3) Hyderabad (Bolarum)—Bombay ...	22 48·85	22 49·52	+ 0·67
(4) Bellary—Bombay	16 26·96	16 27·42	+ 0·46
(5) Hyderabad (Bolarum)—Bellary ...	6 21·88	6 22·10	+ 0·22
(6) Madras—Hyderabad (Bolarum) .	6 54·69	6 54·81	+ 0·12
(7) Madras—Bellary	13 16·56	13 16·92	+ 0·36
(8) Bangalore—Bellary .. .	2 37·36	2 37·31	— 0·05
(9) Vizagapatam Madras	12 9·79	12 9·69	— 0·10
(10) Vizagapatam—Bellary	25 26·39	25 26·61	+ 0·22
(11) Mangalore—Bombay	8 7·37	8 7·55	+ 0·18

The telegraphic circuit errors are as follow :—

				s.
(4)	+ (5)	− (3)	=	− 0·01
(5)	+ (6)	− (7)	=	+ 0·01
(3) + (6)	− (4)	+ (7)	=	+ 0·02
(7)	+ (9)	− (10)	=	− 0·04
(1)	+ (8)	− (7)	=	− 0·16
(8) + (4)	− (11)	− (2)	=	+ 0·18

The first four errors are small, and show the work to be of a high order of accuracy; the two last errors are those of circuits containing the two faulty arcs (1) and (2), which were measured before the defects alluded to in one of the transit instruments had been discovered and rectified; their magnitude is believed to be almost entirely due to this cause.

(79.) It will be noticed that the trigonometrical values are, in almost all cases, greater than the telegraphic. This is partly due to the circumstance that the constants for the Figure of the Earth, which always have been and are still used in the computation of the geodetic latitudes and longitudes of this Survey, are not quite exact; the most modern and exact investigation of the figure—that by Colonel Clarke, C.B., R.E., of the Ordnance Survey—show that our differences of longitude corresponding to the trigonometrical distances between points in Southern India, should be diminished by about $\frac{1}{65\cdot0}$th part of their magnitudes. It is also partly due to local deflections of the plumb-line at the stations of observation, and is in accordance with the results of Captain Basevi's pendulum observations, which indicate a probably greater density in the strata of the earth's crust under the beds of oceans than under continents; for then the plumb-line at stations on the coast would be deflected from the continent towards the ocean, and this would diminish all astronomically determined arcs between stations on the coast and those in the interior, and still more diminish the arcs between stations on opposite coasts of the continent. The excesses of the trigonometrical over the telegraphic arcs which span the Indian Peninsula are 0·63s. = 9″·5 for Madras to Mangalore, and 0·68s. = 10″·2 for Vizagapatam to Bombay, of which probably 3″·0 are due in the former and 5″·9 in the latter instance to the constants used for the figure of the earth, leaving 6″·5 and 4″·3 respectively of excess, which may be due to local attraction of the nature in question.

(80.) On the completion of the operations between Bombay and Mangalore, Captains Campbell and Heaviside proceeded to determine the differences of longitude between Bombay, Aden, and Suez, in order to complete the connexion between England and India, of which the section from Greenwich to Suez had already been executed on the occasion of the Transit of Venus in 1874, under instructions from Sir G. B. Airy, K.C.B., Astronomer Royal.

(81.) It now became necessary to modify very materially the procedure which had been adopted for the previous operations, in order to meet the transition, from land-lines of telegraph and their several recorders, to submarine cables and the syphon recorders by Sir William Thomson, which are exclusively used in the offices at the extremities of the cables at Bombay, Aden, and Suez. In his narrative report, from which copious extracts are given in the Appendix, Captain Campbell has given an excellent description of the manner in which this transition was effected, pointing out the various expedients which suggested themselves from time to time, until at last a method of operation was devised which was found to work very satisfactorily as regards the specific object in view, and also to occasion the minimum amount of interference with the regular work of the telegraph offices. The chief merit claimed for the method devised by Captain Campbell for comparing clocks through a cable is that it may be called automatic, inasmuch as no personal equation of observing or repeating signals can enter. It is believed that this is the first instance of such perfection of method having been attained, as it was not possible in observations taken before the introduction of the syphon recorder. Great credit is due to Captain Campbell for the admirable manner in which he surmounted the various difficulties presented to him at almost every turning; and to Captain Heaviside for his valuable co-operation.

(82.) The Government has also much reason to be indebted to the Eastern Telegraph Company for granting the gratuitous use of their cables, not only

during the actual work of signalling, but during the preliminary tentative measures; these involved an amount of intercommunication by cable which would have added very seriously to the cost of the operations, had it been charged for at the usual rates.

(83.) The values of differential longitude which were obtained are—

		h.	m.	s.
Bombay — Aden	=	1	51	19·98
Aden — Suez	=	0	49	42·66

The value of Madras Bombay which has been obtained by Captain Campbell, from a combination of the arcs already capitulated, is 0h. 29m. 43·54s. The longitude of the station at Suez relatively to the Greenwich Observatory is 2h. 10m. 13·24s. as determined under the direction of Sir G. B. Airy, Astronomer Royal. Thus the longitudes now determined for India are—

	h.	m.	s.	
The Station at Aden	= 2	59	55·89	East of Greenwich.
The Observatory at Bombay	= 4	51	15·88	
The Observatory at Madras	= 5	20	59·42	

(84.) The longitudes of all places in India are usually referred to Greenwich through the Madras Observatory, the position of which has been determined at various times by astronomical observations. The latest determination of that nature is 5h. 20m. 57·3s. — 80° 14′ 19″·5 east of Greenwich, which has for many years been the accepted value, and is given in the current Nautical Almanacs; this value is thus shown to be 2·12 seconds of time, or 31·8 seconds of arc, in defect of what may now be considered to be most probably the true value.

No. XIII.—GEOGRAPHICAL.

HIMALAYAN EXPLORATIONS.

(85.) During the year 1876, the Mullah, one of our explorers, made a survey up the course of the Indus from the point where it enters the plains above Attok, to the point where it is joined by the river of Gilghit. All other portions of the course of the Indus—from the table-lands of Thibet, where it takes its rise, down to its junction with the ocean—have long since been surveyed; but up to the present time this portion has remained unexplored, and has been shown on our maps by a dotted line, the usual symbol for geographical vagueness and uncertainty. Here the great river traverses a distance of some 220 miles, descending from a height of about 5,000 feet to that of 1,200 feet above the level of the sea. Its way winds tortuously through great mountain ranges, whose peaks are rarely less than 15,000 feet in height and culminate in the Nanga Parbat, the well-known mountain whose height, 26,620 feet, is only exceeded by a very few of the great peaks of the Himalayas. The river in many places is hemmed in so closely by these great ranges that its valley is but a deep-cut, narrow gorge, and, as a rule, there is more of open space and culturable land in the lateral valleys, nestling between the spurs of the surrounding ranges, than in the principal valley itself.

(86.) The positions and heights of all the most commanding peaks in this region had been long fixed by Captain Carter's observations at trigonometrical stations on the British Frontier line; but no European has ever yet penetrated into it.* Very difficult of access from all quarters, it is inhabited by a number of hill tribes, each independent and suspicious of the other, who are in a great measure separated and protected from each other by natural barriers and fastnesses. As a whole, the region has never been brought into subjection by any of the surrounding powers. Each community elects its own ruler, and has little intercourse with its neighbours; and with the outer world it only communicates through the medium of a few individuals who have the privilege of travelling over the country as traders. The Mullah possesses this privilege,

* Several itineraries which were obtained from native information are published in Dr. Leitner's Dardistan, and they have been combined together, with considerable ingenuity and very tolerable success, by Mr. Reverstein, in a map published in the Geographical Magazine for August 1875.

and thus in the double capacity of trader and explorer, he traversed along the Indus, and through some of the lateral valleys, leaving the others for exploration hereafter.

(87.) This work done, he proceeded, in accordance with his instructions, to Yassin, marching through the Gilghit Valley, but not surveying it, because the labours of the lamented Hayward, who was murdered at Yassin, already furnished us with a good map of that region. From Yassin he surveyed the southern route to Mastuj through the Ghizar and Sar Laspur Valleys; this has furnished an important rectification of a route which had hitherto been laid down from conjecture only, and very erroneously; for the road, instead of proceeding in a tolerably straight direction from Yassin to Mastuj, as was supposed, turns suddenly from south-west to north-north-east at Sar Laspur, which is situated at some distance to the south of the direct line, in a valley lying parallel to the valley of Chitral. At Mastuj the Mullah struck on to his survey of the route from Jelalabad, *viâ* Dir and Chitral, to Sarhadd-i-Wakhan, in 1873, and then proceeded along that route towards the Baroghil Pass, as far as the junction of the Gazan with the Yarkhun river, and then along the northern road from Mastuj to Yassin. This road turns up the Gazan Valley, crosses the Tui or Moshabar Pass—which is conjectured to be probably not less than 16,000 feet in height—and, after traversing a deep crevassed glacier for a distance of about eight miles, reaches the point where the Tui river issues in great volume from the glacier; the road then follows the course of the river down to its junction with the Warchagam river, a few miles above Yassin.

(88.) Returning to Sar Laspur, the Mullah next surveyed the route to the south-west, up the valley leading to the Tal Pass. This pass is situated on a plateau of the range which connects the mountains on the western boundary of the valley of the Indus with those on the eastern boundary of the valley of Chitral, and is generally known by the people of the country as the Kohistan. The sources and most of the principal affluents of the Swat and the Panjkora rivers take their rise in this region, all the most commanding peaks of which were fixed by Captain Carter's triangulation; but of the general lie of the valleys relatively to the peaks, nothing at all definite has been known hitherto. The Mullah has done much to elucidate the geography of this region. On crossing the Tal plateau he descended into the Panjkora Valley, and traversed its entire length down to Dodbah, at the junction of the Dir river with the Panjkora, where he again struck on his route survey of 1873.

(89.) It would have been well if he could then have gone down the Panjkora to its junction with the Swat river, but circumstances prevented him from doing so. He therefore travelled along the Havildar's route of 1868 as far as Miankalai, and then surveyed the road to Nawagai and on to Pashat in the valley of Kunar; and finally, returning to Nawagai, he surveyed the road from there down to the British fort of Abazai.

(90.) Thus the explorations of the Mullah have added much to our knowledge of the geography of the interesting regions lying beyond our northern Trans-Indus Frontier. A good deal, however, still remains to be done before our knowledge of these regions is as full and complete as it should be, and every effort will be made to carry out further explorations as soon as possible.

(91.) The accompanying sketch map has been constructed to illustrate the Mullah's operations; it also shows the localities where more information is wanted. In the north-east corner the results of a recent reconnaissance of portions of the Karambar and the Nagar Valleys by Captain Biddulph are given, but somewhat modified from his map of the country.

SKETCH MAP

CONSTRUCTED TO ILLUSTRATE

EXPLORATIONS

MADE IN CONNECTION WITH THE OPERATIONS OF

THE GREAT TRIGONOMETRICAL SURVEY OF INDIA

by Mullick

1868.

Scale 1 Inch. = 32 Miles or 1/1013760

0 16 32 64 96 128 Miles

EXPLORATIONS.

(1). The source of the River Indus, from Ash to Banj.

(2). The route from Tanan to Mastuj, via Sar Lakpar.

(3). The route from Mastuj, via the Tui or Mashelter Pass to Barkulti.

(4). The route from Sar Lakpar to the Tui Pass and down the Panjkora River, to its junction with the Ilti River.

(5). The route from Wardaluk, via Nanagi to Peshur or New Kanur.

(6). The route from Nanagi to the Fort of Alladai.

REFERENCES.

Hill peaks fixed by the G. T. S. are shown by triangles, thus ▲; their heights when determined are given opposite them in feet.

Hill peaks fixed by Lieutenant Harward are shown by small circles, thus ○; and the determinations of heights are distinguished by the letter (H.) appended, thus H 20000 (H.).

Lieutenant Harward's journeys, between and beyond Gilgit and Yasin, have been laid down under the direction of the compiler of this map.

Captain Biddulph's routes in Chitral, Kafiristan and Puger valley have also been plotted off; the heights are distinguished by B.C letter (B.) after them.

The route from Ut to Mastuj via Chitral was from Ut to Kunar and Asmar, and other from the most which was executed to illustrate the explorations by the Survey off the Mission in 1873-74.

Published by order of the Right Hon. the Secretary of State for India in Council.

Photo-zincographed at the Office of the Superintendent, Great Trigonometrical Survey, Dehra Dun, August 1877.

No. XIV.—THE HEAD QUARTERS OFFICES.

CALCULATING, PRINTING, DRAWING, AND PHOTOZINCOGRAPHIC; CORRESPONDENCE; STORES.

(92.) The simultaneous absence of Messrs Hennessey and Cole, and of myself, on furlough during the greater part of the year 1876, rendered it necessary for Major Thuillier, when officiating for me as Superintendent, to assume the direction of the Drawing and Photozincographic Offices, while Major Herschel directed the Calculating and Typographic Offices. This arrangement was continued during the interval from April to October 1876—when Mr. Hennessey, having returned from furlough, was appointed to officiate for me in the place of his junior, Major Thuillier—up to the 13th January 1877, when I returned. Mr. Hennessey then resumed the general charge of the four offices with assistance from Major Herschel, until Mr. Cole's return on the 27th March, when Major Herschel was set free to resume his duties in connection with the reduction of the pendulum observation, by Captains Basevi and Heaviside.

PERSONNEL.

J. B. N. Hennessey, Esq., M.A., Deputy Superintendent, 1st Grade.
Major H. R. Thuillier, R.E., Officiating Deputy Superintendent, 1st Grade.
Major J. Herschel, R.E., Deputy Superintendent, 2nd Grade.
W. H. Cole, Esq., M.A., Assistant Superintendent, 1st Grade.

Computing Branch.

Mr. C. Wood, Surveyor, 3rd Grade.
„ H. W. Peychers, Surveyor, 4th Grade.
Baboo Gunga Purshad, Computer.
„ Cally Mohun Ghose, „
„ Kally Coomar Chatterjee, Computer.
and
Eleven other Computers.

Printing Branch.

Mr. M. J. O'Connor, Printer.
Sixteen Compositors and Apprentices.

Photozincographic Branch.

Mr. C. G. Ollenbach, Zincographer.
„ C. Dyson, Photographer.
Two Apprentice Photographers, one Native Draftsman, two Apprentice Draftsmen, and a Map-keeper.

Drawing Branch.

Mr. G. W. E. Atkinson, Surveyor, 3rd Grade.
Jafir Khan.
Two other Draftsmen, four Assistant Draftsmen, also some Apprentices and Map-colorists.

Correspondence and Stores.

Harry Duhan, Esq., Personal Assistant.
Mr. L. H. Clarke, Surveyor, 2nd Grade.
Baboo Raj Krishna Mukerjee.
and
Two other Writers.

(93.) Major Herschel's investigations of the influence of local attractions, and the variations of continental and oceanic gravity, on the swings of the pendulums, had necessarily been laid aside during the entire period—upwards of a year—when he was holding charge of the Computing Office, as his time was then very fully occupied with the duties of that office. The interruption was, however, found to be not without advantage, leading to a better arrangement and closer grasp of the subject, and more clearly defining the limits within which reductions might be profitably undertaken, so that the value of the results may be at all commensurate with the labour of the numerical calculations. It has thus been ascertained that much of the labour which is usually bestowed on reductions of this nature is unnecessary, and that approximate formulæ, the application of which involves far less of calculation, may be employed with sufficient accuracy for the required purposes, seeing that there is very much of uncertainty as to the true values of some of the principal facts which enter into the investigations. In his report on the prosecution of the reductions (Appendix, page 63—a), Major Herschel dwells on the failure of any known conditions of the earth's form or constitution to explain the variations of gravity which are evidenced by the pendulum; but he arrives at the conclusion that, though pendulum results are subject to errors which we have no prospect of eliminating, their number should be increased, both locally and generally over the whole globe.

(94.) Much valuable work has been done during the year in the Computing Office. The final reduction of the North-East Quadrilateral—that section of the Great Triangulation which includes all the principal chains of triangles situated to the north of a line running from Sironj in Central India through Calcutta

to the Eastern Frontier, and to the east of the meridian of Sironj—was commenced during the previous year under Major Herschel's supervision, and has been completed this year. The reduction was effected in continuation of, and on the same principles as, those of the North-West and the South-East Quadrilaterals, which have been described in previous reports in sufficient detail to obviate the necessity for any further exposition of the subject in this place. Various other calculations and reductions have been made, the principal of which are given in the extract from Mr. Hennessey's report in the Appendix.

(95.) Considerable progress has been made since my return from Europe with the 2nd volume of the Account of the Operations of this Survey, the greater portion of which is now completed and has been passed through the press. It gives a brief history of the operations, a full description of the procedure which has been followed, and of the instruments which have been employed in the measurements of the angles, and all the mathematical formulæ which are used in the reductions. It also gives full details of the simultaneous reduction of the North-West Quadrilateral; these it has been found very difficult to present in a compact form, divested of the greater portion of the numerical results which were obtained during the successive stages of the calculations, and yet containing every factor which is essentially necessary to enable the results to be readily tested and verified; for the calculations are exceedingly numerous and intricate, and somewhat difficult to follow.

(96.) The Drawing Office has been chiefly employed in the preparation of charts of the triangulation in illustration of the synoptical volumes which are published on the completion of the final reductions, and also in continuing the charts of levels which give the results of all existing lines and systems of levels, by whatever department executed, combined together and reduced to a common datum. Maps have been constructed to illustrate the explorations of the Mullah, and the report on Gilghit by Captain Biddulph. And much good work has been done in the examination of maps and charts sent in by the survey-parties for publication.

(97.) The Printing and Photo-zincographic Offices have been very fully employed, and, in fact, have found much difficulty in grappling with the amount of work which they have had to deal with, and which increases annually. Heavy arrears had been allowed to accumulate towards the end of the previous year, which was in some degree owing to a want of attention on the part of the topographical draftsmen to the style of drawing required for maps which have to be reproduced by photo-zincography: for a map may be very beautifully executed, and yet be unsuited for reproduction by this cheap and expeditious process which is so valuable when speedy publication is wanted; but the arrears were to some extent also due to a want of method in the working of the office. They have now been nearly all cleared off, and a very short interval now elapses between the receipt of a map from one of the survey-parties and its publication after due examination.

(98.) Mr. Hennessey warmly acknowledges the valuable and varied assistance which he has received on all occasions from Mr. W. H. Cole, M.A.; he also reports very favourably of Mr. Wood, Mr. Peychers; Baboo Gunga Pershad, and Baboo Cally Mohun in the Computing Office, and of Mr. Atkinson in the Drawing Office, and satisfactorily of Messrs. O'Connor, Ollenbach, and Dyson.

(99.) Mr. H. Duhan, my Personal Assistant, has rendered much valuable service in the general supervision of the Correspondence Office; and Mr. L. H. Clarke has worked heartily and well in the performance of his varied duties.

J. T. WALKER, *Colonel, R.E.,*
Superintendent, Great Trigonometrical Survey.

CALCUTTA,
31st December 1877.

Abstract of the Out-turn of work executed by the Great Trigonometrical Survey Parties during the Survey year 1876-77.

Description of Details.	Madras Coast Series, 24-inch Theodolite.	Assam Valley Triangulation, 12-inch Theodolites.	Burmah Secondary Triangulation, 12 inch Theodolites.	Eastern Frontier Series, 24-inch Theodolite.	Eastern Sind Series, 24 inch Theodolite.	Railway Survey.	General Topographical Survey.	Kumaon and Garhwal Topographical Survey.	Spirit-Levelling Operations.	Total.
Number of principal Stations newly fixed ...	15	...	...	12	26	...	..	...	...	53
Number of principal Triangles completed ...	18	...	...	17	32	...	...	...	...	67
Area of principal Triangulation, square miles ...	532	...	...	2,032	2,455	...	...	...	...	5,019
Lengths of principal Series, in miles .	52	...	...	92	125	...	...	...	...	269
Average Triangular error, in seconds	0·81	...	...	0·16	0·36	...	...	...	...	...
Average probable error of Angles, in seconds ± ...	0·17	...	...	0·12	0·14	...	...	...	...	..
Astronomical Azimuths of verification observed ...	1	...	...	...	1	...	...	...	.	2
Number of principal Stations selected in advance ...	5	...	...	13	21	..	...	...	...	39
Lengths of principal Approximate Series, in advance ...	20	...	...	56	98	...	...	...	...	174
Number of Pillars and Platforms constructed for principal Stations ...	10	...	...	14	30	...	...	...	...	54
Number of Scaffolds erected for principal Stations ...	13	...	...	...	...	...	...	...	...	13
Number of principal Stations placed under official protection ...	13	...	22	15	24	...	...	...	...	74
Number of principal Stations protected and closed ...	7	...	44	20	24	..	...	...	...	95
Number of Secondary Triangles of which all three angles have been observed ...	....	22	32	9	3	160	112	35	...	373
Number of Secondary Triangles of which only two angles have been observed ...	...	256	104	46	55	1,554	315	186	...	2,516
Number of Secondary Stations the positions of which have been fixed	...	21	...	...	...	82	89	39	...	232
Number of Points fixed by intersection but not visited ...	2	112	60	20	3	891	156	96	...	1,340
Number of Revenue Survey Stations and Boundary junction pillars fixed by Triangulation ...	...	...	...	...	28	...	...	...	...	28
Number of Stations and Points the heights of which have been determined ...	...	116	90	25	32	482	78	83	...	906
Length of Secondary Series, in miles .	...	63	176	...	8	...	...	70	...	317
Area of Secondary Triangulation, in square miles ...	...	477	2,522	...	140	2,062	2,489	870	...	8,561
Area embraced by Triangulation to hill-peaks, in square miles ...	...	6,100	2,100	2,400	...	...	...	13,000	...	23,600
Number of Pillars, Platforms, or posts for Secondary Stations, constructed or repaired ...	...	33	14	6	5	279	467	...	...	905
Length of Boundary lines and Check-lines traversed, in linear miles ...	...	...	...	...	...	752	1,965	...	...	2,717
Area Topographically surveyed on scale 1 inch = 1 mile, square miles	...	...	...	...	..	...	...	950	...	950
Area topographically surveyed on scale 1 inch = 1 mile, square miles	...	...	...	...	...	...	..	640	...	640
Area topographically surveyed on scale 2 inches=1 mile, square miles	...	...	...	...	...	1,716	1,988	...	...	3,704
Number of miles of rays cleared ...	272	250	28	2	20	...	...	...	...	572
,, ,, pathways made	...	31	...	30	...	...	...	...	...	61
,, hill-tops cleared of forest and jungle ...	..	3	16	24	...	...	...	...	...	43
Number of miles levelled over ...	...	...	...	...	...	...	...	...	375	375
,, permanent Bench marks fixed ..	...	...	...	..	...	...	...	...	306	306
Astronomical Azimuths of verification computed ...	1	...	...	...	1	...	...	...	...	2
Number of principal Stations the elements of which have been computed	15	...	...	14	24	...	...	..	...	53
Preliminary Charts of Triangulation	1	1	2	1	1	...	...	...	...	6
Number of Secondary Stations the elements of which have been computed	...	135	92	27	33	969	...	66	...	1,322
Number of Points fixed by traverse and their elements computed ...	37	...	.	...	1	2,131	6,041	...	...	8,210
Barometrical determinations of heights	...	...	...	...	...	...	..	192	...	192
Number of Topographical Maps completed ...	...	...	...	...	...	14	32	5	...	51

APPENDIX.

EXTRACTS FROM THE NARRATIVE REPORTS

OF

THE EXECUTIVE OFFICERS IN CHARGE

OF

THE SURVEY PARTIES AND OPERATIONS.

I.—Extract from the Narrative Report, dated 15th August 1877, of Captain T. T. Carter, R. E., late in charge Madras Party.

On my arrival at Bombay, on return from furlough to Europe, I proceeded to Bangalore, and on the 20th of November took over charge of the Madras Party from Captain W. M. Campbell, Royal Engineers, who had held charge of the same during the absence on leave to Europe of Major (now Lieutenant-Colonel) Branfill.

The party, consisting of the officers and establishment as per margin, were despatched as soon as all arrangements could be made, and arrived at Tanjore on the 1st December.

Captain Carter, R. E., Deputy Superintendent, 3rd grade.
Mr. G. Belcham, Surveyor, 4th grade.
Mr. C. D. Potter, Asst. Surveyor, 1st grade.
Mr. A. H. Bryson, Asst. Surveyor, 3rd grade.
1 Hospital Assistant.
55 Klassies.
14 Burkundazes.
24 Carriers.

State of the work at close of past season.

During the field season 1875-76, the Madras Coast Series had been advanced by two hexagons observed, and by the selection of sites and construction of the masonry pillars for the stations of two more hexagons.

Mánikkamkottei.
Okkúr.

The angles at the two stations of continuations had also been observed during the past season; consequently, the scaffoldings which form the platforms both for the observer and signallers had been constructed for three stations of the new polygon. These, however, required repair and looking to before they could be used; the platforms for the remaining three stations of the figure had to be constructed and the rays between stations finally opened out, as they had only been partially cleared the previous season; this was the first work to be done as regarded the Okkúr polygon; with reference to the Mepankád or second hexagon selected in advance, there was still some uncertainty as to whether the two last stations would be visible from the central station.

Karká Kuriehi.

Distribution of officers on first taking the field.

The following distribution of officers was made on first taking the field: Mr. Belcham was directed to proceed to the central station of the hexagon last chosen, and at once satisfy himself that mutual visibility could be obtained between that station and the two stations in advance referred to above, and, if not, to select other sites; he was then to superintend the buildings of the scaffoldings at two stations and open out the ray between them. Mr. Belcham set to work with his usual zeal, and luckily it was found that there was no difficulty in obtaining visibility between these stations; and by the end of the month he had completed this portion of the work allotted to him. Mr. Potter was directed to build the scaffolding at one station and to clear the rays from it; subsequently, to repair the scaffolding at another (erected the previous season), and to raise the pillar there from 2 to 8 feet: as it was found that the height of eye was not sufficient; he began his work on the 10th of December.

Mr. Bryson was deputed to carry out similar work which he commenced on the 16th of December. I proceeded myself to Shemblavayal P. S., the first station from which observations had to be taken, and arrived there on the 18th of December, having visited Messrs. Belcham and Potter on my way.

Prevailing scarcity of grain and water.

As was natural to expect, having taken the field with a party quite new to me, there was some delay at first starting; moreover, owing to the famine prevailing in Southern India, there was a difficulty in procuring provisions; rice was selling at 5 seers for a rupee, the people had migrated in large numbers to Ceylon, and those that were left seemed little inclined to part with their grain; moreover, there was a threatening of a water famine, the tanks at this time (middle of December) being nearly dried up. However, by suitable arrangements, the difficulty as to feeding the camp was got over, and all fear of a water famine was over, when, on the 23rd of December, heavy rain fell and continued to the 26th.

Observations were begun at Shemblavayal P. S. on the 27th of December, and the station was completed on the 30th.

Commencement and final observations by Captain Carter and Mr. Belcham.

From Major Branfill's report of the previous season's work I was aware that Mr. Belcham had taken a considerable part in the "principal observations" of that year. I was also desirous of obtaining from Mr. Belcham a knowledge of Major Branfill's mode of procedure with reference to the observatory work, as well as an insight into the characters of the different men of the establishment. I therefore decided to call him in to assist in taking observations; the result was very satisfactory, and it enabled me to complete the observations at seven stations by the end of January. The plan I adopted was to observe on one zero while Mr. Belcham recorded; the next zero we changed places, Mr. Belcham observing while I recorded. There was no native recorder attached to the party, and, had I not adopted this plan, I should have been obliged to recall Mr. Bryson to record, and as he has had no experience in observing with a 24"

theodolite, his services would only have been of use as a recorder, and the observations at these seven stations would probably have taken double the time. Mr. Bryson was as able as Mr. Belcham to construct scaffoldings, and it was also desirable that he should have some practice in selecting and building stations. I think credit is due to Mr. Belcham that he is able, when necessary, to take a share in the principal observations.

Final observations continued and completed by Captain Carter.

On the completion of observations at Mepankâd, Mr. Belcham was deputed to continue the approximate work. Mr. Bryson was recalled as observatory recorder, and continued as such during the remainder of the field season; he was also employed in fixing by "theodolite and chain traverse" any buildings of a permanent nature in the vicinity of the principal stations: observations were completed at eight more stations by the end of the field season; at the station of Pâtharankortei, an azimuth of verification was observed, the two stars selected being α Ursæ Minoris (polar star) and B Ursæ Minoris for eastern and western elongation respectively.

Mr. Belcham.

Mr. Belcham, on being relieved from his duties in the observatory on the 1st February, proceeded to take up the approximate work and was employed on this duty till the close of the field season. Although he only completed the selection and building of three stations and the clearing of the rays to and from the same between the 5th of February and 14th of April, this slow progress appears to have been entirely due to the unfavourable nature of the ground and the heavy cutting that had to be got through. The aspect of the country had altered very considerably, consisting now of paddy fields hedged round with babul trees very difficult to get through, and the ground much cut up with water-courses.

Mr. Potter.

Mr. Potter having completed the repairs at stations, as directed, proceeded to Mepankâd P. S., and in conjunction with Mr. Bryson (who was directed to work under Mr. Potter's orders), had completed the buildings of the scaffoldings of, and the clearing of the rays between, the stations of the Mepankâd (or second) polygon by the 11th of January. Mr. Potter then proceeded to take in hand the next figure, assisted by Mr. Bryson. Mr. Bryson was recalled to act as observatory recorder on the 3rd of February, and the approximate work was continued by Messrs Belcham and Potter. Mr. Potter's progress had been very good; in a little over a month he had selected and built three stations with their scaffoldings and cleared the rays between the same, but he now experienced the same difficulties on the eastern flank as Mr. Belcham, who was working on the western flank, and his progress was consequently slower than at the commencement of the season; he closed work on the same date as Mr. Belcham, *viz.*, the 14th of April.

Paruttikôttei.

Mr. Bryson.

Mr. Bryson's work has been already mentioned.

Messrs. Belcham, Potter and Bryson worked cheerfully and well, and I have every reason to be satisfied.

Secondary triangulation.

Little or no secondary triangulation could be done, the country lying low, without much difference in level, and in most places thickly covered with mango and palmyra groves; points observed to form one station were seldom seen from another. A considerable number of masonry buildings (chiefly temples) were fixed by a "theodolite and chain traverse" to serve as points from which the position of the principal stations could be found in case the pillar and mark-stones above ground should at any time have been removed; their position being known will also be useful in any future survey of the country, as they are buildings likely to endure for a considerable time.

Connection with Colonel Lambton's work executed in the beginning of the present century.

As our triangulation was approaching that of Colonel Lambton's executed in the year 1800, I endeavoured to find out if any of his marks could be found on the different pagodas shewn on the chart of his triangulation, which were evidently used by him as stations of observation. The pagodas of Munargudi, Alangudi, Combaconum and Tanjore were examined for this purpose, as well as the *goparam* or "gateway" leading into the enclosure in which the pagoda stands; the general description given of these stations is "on the pagoda," though in all probability the instrument was placed on some part of the *goparam*, which is usually a much loftier structure than the pagoda or temple. I regret to say that in no instance did I find a mark. An endeavour was also made to find the terminal marks of the Vellum Base Line in case it was thought desirable to connect it with our triangulation, but without success, the only station of Colonel Lambton's triangulation, the exact position of which can be identified as far as the work has gone at present, is that at Budalur, the mark-stone of which is protected and kept in repair by the civil authorities. The question of identification of these stations of Colonel Lambton's triangulation I brought to the notice of Colonel Branfill on his re-assuming charge of the party.

Protection of stations.

The whole of the stations at which final observations were completed were protected and made over to the civil authorities as directed in Departmental orders No. 1 of 1866. Generally, the protecting mound of earth was turfed over; the station was further protected by having a cactus hedge planted round it, which also served to shew the limits of the ground taken up by Government. In

several cases this small plot of ground was bought, and I was in communication with reference to the purchase of the same in every case, and a transfer of the land from the owner's name to that of Government on the land registers; there would always then be a permanent record for reference in future years as to the position of the station.

Instrument.

The 24-inch theodolite No. 2, by Troughton and Simms, worked well, though there was a tendency for the readings to diminish on the return to the same point, and this whether the telescope was moved from right to left, or left to right; it was particularly perceptible when observing the azimuth at Pallicorankotei, where the referring mark was being constantly intersected. I attribute it to the expansion and contraction of the 17½ feet stand which in this party has taken the place of masonry pillars. In the beginning of the season the stand was protected from the prevailing wind from the north-east; the extremes of temperature were not so great, and it was not till March that I observed this peculiarity. By protecting the stand on all four sides, I found that, though there was still a tendency for the readings to diminish, the decrements were much less. I must mention a curious feature in the case, *viz.*, that though there was this tendency for the readings to lessen each time that the telescope was pointed at the same object, the levels attached to the body of the instrument (one of them a particularly sensitive one) remained very constant. The triangular errors are large, and this I can only account for by the rays being grazing, and often passing over tanks and rice swamps; the signals were steady, and I had only on one occasion to stop work on this account, and this unsteadiness was due to the lamp-man neglecting to isolate his lamp from the part of the platform on which he sat: of course, there is a tendency for such high scaffoldings to oscillate, the guy ropes want constant tightening, and the plumbing looking to; the scaffoldings (from which the signal was shewn) averaged 45 feet in height, on one occasion one had to be raised to 60 feet to overcome a rise in the ground, and this was done without much difficulty. The deflection at this height was very slight, even in a high wind, verifying the opinion of Captain Campbell expressed in paragraph 3 in appendix to Major Branfill's report of last year. The scaffoldings were built of the palmyra palm-tree, which was generally procurable near the station; it is, however, heavy and cumbersome to move; the areca palm-tree, which I believe was used on the southern portion of the series as well as on the Ceylon connection series, was not procurable in the district, and the officers employed on the construction of these scaffoldings had to make the best of what timber could be got on the spot.

Health of the party.

The health of the party was very good; two men were attacked by cholera on first taking the field, one of whom died; and this was the only casualty.

LIEUTENANT-COLONEL BRANFILL'S LIST OF PLACE-NAMES.

Proper names of Stations and Places given on the preliminary charts of the Madras Party, Great Trigonometrical Survey of India, for the seasons 1875-76 and 1876-77, along the coast of Madura and Tanjore, from Rámesvaram to Point "Calimere" (Kallimédu).

"Adrampatam" ... ... See Indian Atlas Sheet No. 80	short for Adi-víra-Ráma-pattanam, the (seaport) town of Adi-víra Ráma, one of the Pándyan princes of Madura, its founder.
Amanakkamunei	"*Castor-oil plant headland*"—from *ámanakkam*, the castor-oil plant which grew there; and *munei*, a point or headland.
Arantángi	"*Charity station*"—from *aram*, charity; and *tángi*, a support.
Avideiyár Kóvil	name of a large temple (*kóvil*) in the south of Tanjore, from Avudayár one of the names of the lingam, the sacred phallic symbol of Siva; *ávudayár* means "*ox-owner*" (*ávu* =, ox), and Siva is commonly represented as riding on a bull.
"Calimere" ... ... See Indian Atlas Sheet No. 80.	properly Kallimédu, "*Euphorbia mound*," the north-east headland of Palk's Straits (the Argaric gulf), between India and Ceylon. This point is also called *kódi* = the point, the same as the other or southernmost extremity of the gulf at the south extremity of Rámésvaram.
Chevidan Kóttei	"*Deaf one's fort*" (*chevi* = ear)—*chevidan*, a deaf man; and *kóttei* a fort or fortified village.
Dévipattanam	"*Devi's-town.*" *Dévi* = "*the goddess*" is a name of Siva's consort, Párvati.
Elunúthimangalam	from *élu*, seven; *núru*, a hundred; and *mangalam*, delight, joy, matrimony.
Gandhamána Parvatam	the little eminence about a mile north of Rámésvaram temple, so named after one of the leaders of Ráma's army when attacking Lanka (Ceylon), as told in the Rámáyana.
Gópuram	the lofty tower or spire over the entrance gateway of a temple or town in Southern India—from *káppu*, a pointed roof, spire, or dome, which, perhaps, is from the same root as cupola, coping, cap, &c.: compare Hind. *kubba*, a dome.
Kád *or* Kadu	a wilderness, jungle; an untilled or unirrigated field, fit for dry crops only; the root *ká* means a grove, wood, or garden; also a beam or boom; cf. S. *káth*, wood timber.
Kakkrí Kóttei	"*Kaka-Ráman's fort.*"

Kallá Kóttei	"*Stoneless fort*"—from *kal*, a stone; *illei*, the negative = without; and *kóttei*, a fort.
Kalúrunikád	"*Stone-tank-field*"—from *kal*, a stone; *úruni*, a common village tank, a horse-pond; and *kádu*, a jungle, a dry or untilled field.
Kánád	? "*Wilderness*"—from *kán*, a jungle, forest; and *nádu*, a country, district.
Karká Kurichchi	"*Karkan's settlement*"—from the proper name of a man, and *kurichchi*, a small village or hamlet, strictly of mountaineers or foresters.
Kodikulam	properly *kódiyar kulam*, and said to be from *kódiyar*, robbers, because this village had been repeatedly attacked and spoiled.
Kollei	a field, enclosure; a dry unirrigated field, high ground, a grove; met with repeatedly in South Tanjore, but not noticed further south near the coast.
Kollukkádu	"*Grain-field*"—from *kollu*, the horse-gram (vulg. *kulti*) of Southern India.
Kulamangalam	from *kulam*, a tank or reservoir; and *mangalam*, prosperity.
Manigandi	"*Bell-ringer's(-village)*"—from Sanskrit *mani*, a bell; and(. . . . .), a word meaning to strike. This village is said to have been given to an attendant of the Tiruvádáni temple, whose duty it was to perform the bell-ringing there; a former name of the place was *Márgandayarpuram*.
Mánikkamkóttei	"*Manikkam's fort*;" *mánikkam*, a ruby, from (Sanskrit) *mani*, a gem.
Mánúr	Derivation uncertain.
Maruthangón Vidutkí	? "*Hermit's lodge*"—from *maru*, the marriage-feast, a ceremony; *thangón*, one who does not remain, an absentee, truant; and *vidutkí*, a lodging-place, a separate apartment; solitariness, separation.
Masáaa Karei	"*Cemetery shore*." The Hindu pilgrims who die at Rámésvaram are commonly buried at this spot, and their bones lie scattered on the surface, or but half-buried in the sandy waste near the sea-shore. Hindu burning or burying places are usually on the bank (*karei*) of a river or tank.
Mayivayal	"*Peacock's field*"—from *mayil*, a peacock (perhaps from one of the noises or calls he commonly makes. In Canarese the corresponding name is *navil* or *naal*, but the Tamil *mayir*, and the Canarese *nayiru*, both mean hair, a tuft of hair, and may well refer to the peacock's tuft or crest.)
Mélapattu	"*Upper* (=*west*) *ville*." *Méle* is very frequently used in contradistinction to *kíle* which first means under, below, and hence, eastern, as the country of Southern India falls as you go eastward. *Pattu* is a common suffix to place-names in South Tanjore, and seems allied to *patti* a cattle-fold, a hamlet, also to *pattanam* (*patam*) *pat*, and possibly to *pettei* and *pádi*, &c.
Mópankád	a vulgar form of Mérpaneikádu—"*West palm jungle*"; *mér* for *mélé* upper, i.e. western; and *panei*, the palmyra.
Mukutu kollei	"*Corner field*"—from *mukku*, a nook or corner; and *kollei*, a field or enclosure. Another place near this, Kóna kollei, has the same signification.
Nádankádu	Nádán is a title amongst the Shánárs (toddy-drawers), and *nádan* an epithet applied to the Chola kings.
Nariyankádu	? "*Fox-hurst*" "*Dwarfs-wood*"; *nari* means a fox; *nariyan*, a man as cunning as a fox; it also means a dwarf.
Nayenár Kóvil	"*Nayenár's temple*"; *náyanár*—lord, master, a title applied to Siva from the same Sanskrit root as *náyak*, a leader (*naik*), and *Náyar*, the Nairs, or honoured Súdras of Malabar.
Noduvá Kóttei	"*Long fort*"—from *nedu*, long (not to be confounded with *nadu*, middle) and *kóttei*, a fort.
Neduvan Tivu	"*Long island*"—from *nedu*, long, and *tíru*, the Tamil form of Sanskrit *dwipa*, an island. The Dutch Government in Ceylon had a small horse-breeding establishment here, and called the island Delft.
Okkúr	Derivation uncertain, but stated to mean the village of one family, or the "*united village*."
Omathei-nádu	Omathei is the Tamil name of the *datura*, a stupefying plant; and, *nádu*, a district, country.
Pallathivayal	"*Palla-woman's-field*." Pallans are a tribe of low outcastes in Southern India; and *vayal*, a rice-field. This word *vayal*, a field, rice-field, an open plain or flat, is one of the commonest affixes to village names in Southern India. In Canarese it is *bayalu* or *bailu*, but on most of the older maps and charts the name is disguised under many erroneous forms, such as *bile*, *byl*, *vail*, *voil*, *voyal*, &c.
Pasala Kollei	"*Green-field*"—from *pasumei* and *pachchei*, green; and *kollei*, a field, &c.
Pátharan Kóttei	"*Pátharan's fort*."
Pattu Kóttei	*Pattu* is a common affix, and an occasional prefix, to the names of small towns and villages in S. E. Tanjore; it may mean a silk (flag), and perhaps a grant, or a crown, or it may be from the same root as *pattanam*, a town; *patti*, a (cattle) fold; or *pettei*, a town or suburb with shops.

Periya, peru, per	Great-Telegu *pedda*; compare Hind.; *bara* or *bada* great (in Canarese *dodda*).
Peruntámarei	"*Great lotus*;" from *peru*, great, and *tamarei* the lotus.
Pinneiyúr	? "*Rear town*;" *pinnei* means after, farther; compare *Porakudi*.
Porakudi	? "*Back house*," from *pirage*, behind; perhaps because this place is behind, or at the back of, the seaport town of Devipattanam.
Pórakudi	"*Battle dwelling*;" from *por*, fight, battle, and *kudi*, a habitation, dwelling.
Pudukóttei ... . "*Poodoocottah*" of Indian Atlas No. 80.	or Puthu kóttei, "*new fort*;" from *puthiya*, new, and *kottei*, a fort. This is the chief town of the Tondimán Rajah's country, south of Trichinopoly.
Puthu viduthi	"*New lodge*;" from *puthiya*, new, and *viduthi*, a temporary abode.
Púvatúr	"*Flower village*;" from *pu*, a flower, and *ur*, a village.
Retta vayal	perhaps for Irattavayal.="*Double field*;" *rendu* is the vulgar form of *irandu*, two, and *rettayana* of *irattiyana*, double.
Rudra Chintámani	*Rudra*, a name of Shiva, one of the demons or demi-gods, and *Chintamani*, a mythical gem, the philosopher's stone, one of the gems of Swarga (heaven), yielding its owner all his desire.
Sengáttán kudi	a dwelling sacred to Shiva, who prefers the colour red, and sleeps on a bed of red lotus. *Senkadu* or *Chengád* (="*red-wold*," "*bloody field*") is the simple form of the word, from *sem*, red, beautiful, *kadu*, wilderness, and *kudi*, a dwelling.
Shembalavayal	? "*Red-rice-field*," for *sen-nel-vayal*, or more probably for *sempalavayal* ="*bloody field*," "*field of battle*."
Sigankádu	from *sigam*, an acid fruit-tree; the *tamarattei*.
Sirukambur	or Sirukambeiyur said to be from *siru*, little, *vambi*, quarrel, and *úr*, village, *Petty-quarrel-town*, or "*Squabble-ham*."
Tanjore or Tanjá-ur	commonly called by the natives Tanjá-úr, Tanjei, and Tanjam= "*Tanjan's town*"; but the proper name in full is said to be Tanjei-mán-nagaram=*Prince Tanjam's city*. *Tanjam* means a refuge, and *mán* (for *mannan*), a prince, hero, a man in his prime, as in Tondaman, Chéramán.
Thenamanádi	"*South aspect*" or south division; from *ten*, south, southern.
Thondarápattu	? "*Servant's hamlet*" or "*Devotee's abode*;" from *thondan*, a servant, adherent: see Pattukottei.
Tiruchitambaram	a local name of one of the "*Chellambram*" (=*Chitambaram*) temples. *Tiru* means holy, sacred, illustrious, and is the Tamil form of the Sanskrit *Sri*.
Tirunálur	"*Holiday village*;" from *tiru*, holy, *nal*, day, and *ur*, a village, *tirunál*, holiday.
Tiruppu vayal	"*Holy-flower-field*;" from *tiru*, holy, *pu*, a flower, and *vayal*, a rice-field.
Tiruvádáni	name of a place with a considerable temple dedicated to a deity represented as having the face of a sheep, *ádu*, and the body of an elephant, *ánei*; the initial *tiru* means holy, and is the Tamil form of the Sanskrit *Shri* or *Srí*.
Tondamán	The title of the Chief or Rája of Pudukottei, a little to the south of Trichinopoly. *Tondan* means a servant, adherent, devotee; and *mán* (for *mannan*) a prince, a man in his prime: compare *Chéraman*=Prince of Chéra. Tondei or Tondamandalam is the name of the region or country of which Kánchipuram (Conjeveram) was the chief town.
Uranakudi	or Uranakudi, said to be derived from *úr*, a town, *annam*, rice, and *kudi* a dwelling.
Urimunei	a headland in Neduvan Tivu (also called Delft by the Dutch in Ceylon), from the little spiral shells (*uri*) which abound there.
Vánakkankádu	"*Baniyan's field*." *Vánigan*, a trader=*chetti* or *séth*.
Vandal	Dregs, silt, mud from tank-beds; this word appears in the names of villages in Madura, perhaps from their having been built on a ridge of gravel drift, on a spoil-bank, or on the grit heaps left in the waterway of a flooded river or breached tank.
Vayal	a rice-field, an open field or plain; a very common affix to village names on the S.-E. and E. coasts of Southern India: see Pallathivayal.
Vellálankádu	"*Vellálan's jungle or field*." *Vellálans* are an agricultural caste or tribe of Tamils. *Vellánmei* means cultivation, or strictly *flood-ruling*, *i.e.*, irrigation.
Véndán viduthi	? "*Hermit's lodge*." *Véndán*, means not wanted, and is applied colloquially to a sulky, disagreeable man; a recluse.
Venniyur	a hamlet, named after the local goddess *Venniyamman*. Another name for this place is *Muppur* or *Muppeiyur*, a corrupt contraction from *Mummudisolapuram*. There is a local tradition that the three princes (*munu* three, *mudi* crowns), Pándiyan, Solan, and Chéran, once met together here.
Vettanúr	"*Hunter's village*;" from *vedan* a hunter or forester, the name by which the aboriginal wild tribes of Southern India are known, the *Veddahs* of Ceylon.
Vettivayal	"*Worthless field*;" from *vetti* vainness, uselessness.

Viduthi ... ... a lodging-place, temporary abode; this affix to village names seems to be specially common in South Tanjore and East Pudukottei.

Virappavayal ... ... "*Virappa's (rice) field.*" *Virappa* is a common proper name of men in Southern India from *Víran*, a hero, warrior (compare Latin, *vir*), and *appan* a father (compare Hebrew *ab*, Chaldee *abbá*, and Hind. *ap*).

Vitrá vayal ... ... "*Fertile or fruitful field*," from *vittu*, seed.

Provincial place-names common in Rámnád and South Madura, not found at all, or very scarce in South-East Tanjore (see Indian Atlas Sheet No. 80:—

(*a*) éndal ... ... eminence; commonly applied to a hamlet with a small tank in Madura.
(*a*) kanmáy ... ... or kanmay, an irrigation tank, or reservoir of water.
(*a*) karei ... ... a bank, shore, border.
karisal ... ... blackness, the black (cotton) soil; *karshá kulam*=black (soil) tank.
Maravan ... ... (plural Maravar), name of the chief tribe or caste inhabiting the Rámnád and Shivagaugei zemindáries.
(*a*) óḍei ... ... a water-course, stream.
pottal ... ... barren, brackish soil, an arid tract.
taravei ... ... a salt marsh or swamp.
(*a*) úruni ... ... a common village tank.

Provincial place-names newly met with in South Tanjore:—

kollei ... ... a field, enclosure; a dry, unirrigated field; high ground. More common farther north.
pattu ... ... derivation unascertained as yet.
viduthi ... ... a lodging-place, temporary abode. This word seems peculiar to the Pattukottei taluk, east of Pudukottei.

The common South Indian place-names most frequently met with in the extreme South Tanjore Country under notice are:—

(*c*) kádu ... ... a jungle, wilderness.
(*c*) kóttei ... ... a fort, fortified village.
kudi ... ... a dwelling, habitation.
(*c*) kurichchi ... ... a small village, properly a settlement of hillmen or foresters.
(*d*) Pattanam ... ... a town, or seaport town. In 50 miles of this coast there are 24 places of this name (see Indian Atlas Sheet No. 80).
taru ... ... a street; a common term for the little hamlets in each parish or village.
úr ... ... a town or village; probably the commonest affix over all Southern India.
(*d*) vayal ... ... a rice-field, a patch of rice-cultivation, very common also especially in the low country.

The following place-names, so common in other parts of Southern India, are here "conspicuous by their absence":—

Báḍi or pádi, chéri, palli, patti and puram, the commonest Tamil hamlet or village names.
(*a*) áru, éri, gunta, kulam, kuttei, and samundram, affixes meaning river, lake, tank, or pond, &c.
(*b*) médu, paramḍu, párei, and kál, a mound, hillock, or rock, as well as giri, malei, and kunru, a mountain or hill; also nattam, páleiyam, puram, and valasei, common village names with various meanings.

General Note to accompany list of place-names for 1876-77.

The portion of country traversed by the Madras Party of the Great Trigonometrical Survey of India during the past season, skirts the coast of South Tanjore for some 50 miles along the North-western shore of Palks Straits (the Sinus Argaricus of Ptolemy), extending only 20 miles inland, and lies between the deltas of the Veigoi (Véghavati) and the Cauvery (Káveri) rivers. It is crossed by a few unimportant streams which drain the Tondiman or Pudukóttei Rajah's territory) under the Trichinopoly District), but is devoid of any large streams or lakes.

Going north-east-wards from Rámnád, the country changes: the flat, sandy tracts of the south-coast of Madura are left behind, and so are the numerous tanks and the long collecting channels, which are spread over the impervious black (cotton) soil, and the tracts of rice-fields below them.

On entering South Tanjore, though still low and flat, the slope of the country from the sea inland increases to nearly 10 feet per mile. Numerous ridges and depressions, some of them 50 feet in depth, run from W. N. W. to E. S. E.; the former well covered with valuable trees, and the latter with patches of cultivation (*vayal*).

This change of country is sufficiently indicated by the character of the place-names. There are very few towns or large villages, and the village-lands are more like parishes with numerous small hamlets, each bearing the same village name, but distinguished by a suffix indicating the relative position of each within the parish limits.

The following facts may be gathered from an inspection of the map (Indian Atlas Sheet No. 80):—

(*a*) The absence of rivers and irrigation-works.
(*b*) The absence of hills, mounds and rocks.
(*c*) That the country has been to a great extent jungle (*kádu*=wilderness), and occupied by rude, unruly tribes, such as Kallan, Pallan, Valiyan, and Védan.
(*d*) The considerable number of places termed Agrahárum, Mangalam, Pattanam, Pettei, Santei, and Vayal, indicate the presence of a fair proportion of more civilized folk, and tell of trade, agriculture, and brahmanical influence.

Whilst the vegetable kingdom appears to contribute liberally to the onomatology of the district, the animal kingdom is but scantily represented by the peacock, fox, crane, and a few more.

Note regarding the accentuation of the letters O and E in the orthography of South Indian place-names.

The long and short sounds of these vowels, *o* and *e*, are of such frequent occurrence in the Dravidian (*i. e.*, South Indian) languages, that unless some means of distinguishing them are adopted, mistakes as to the meaning and origin of the word in which they occur are unavoidable. It is, therefore, the universal practice amongst writers who have to represent Dravidian words in the Roman character, to accentuate those vowels when long.

A few specimens are given below of words similarly spelt, which require accentuation to distinguish the pronunciation and meaning :—

mel	=	soft.
mêl	=	above.
pen	=	a female.
pên	=	a louse.
veli	=	the air, the open.
vêli	=	a hedge.
veru	=	empty, void.
vêru	=	other.
vetti	=	cutting.
vêtti	=	a (man's) cloth.
kodi	=	a flag, steamer.
kôdi	=	a point, end, score, &c.
kodu	=	give.
kôdu	=	a horn, peak.
kottei	=	a knob, knot nut.
kôttei	=	a fort.
porakudi	=	back-house.
pôrakudi	=	war-house.
totti	=	a pail, trough.
tôtti	=	a sweeper.

In a list of South Indian names drawn up with a view of shewing their origin and root meaning, the accentuation of *o* and *e* when long (as well as of *a*, *i* and *u*, which have been allowed to require accentuation by writers of the North Indian languages) is really indispensable, and has been adopted in the following list of place-names, but not upon the chart accompanying, for want of the necessary authority.

It is hoped that the strict rule for North Indian orthography will be relaxed in this list of South Indian place-names.

B. R. BRANFILL, *Lieut.-Colonel,*

Deputy Superintendent, Great Trigonometrical Survey,
In charge Madras Party.

II.—Extract from the Narrative Report, dated 26th September 1877, of Lieutenant H. J. Harman,, R. E., Assistant Superintendent, 2nd Grade, in charge Assam Valley Triangulation.

2. At the close of the field season, 1875-76, the principal series was complete up to the side "Dibrugarh—Khalkata," the preliminary work of two triangles had been done, the right flank rays of the series were carried up to near the Revenue Survey Pillar at "Poba," and three post stations had been built. Of the branch series to "Jaipur," one final ray had been cut, eight trial rays run (which determined the positions of the six stations of the Series in the plains) and one post station built.

3. Accompanied by Mr. J. F. McCarthy and a small body of men, I left Gauháti on the 16th October, reaching Dibrugarh on the 23rd October.

By 10th November we had cleared three old rays near Dibrugarh, repaired three post stations, obtained angles to the snowy peaks and hills visible from Dibrugarh, and cut two final rays of the "Jaipur Series." One of these rays had to be cut open to the sky throughout its length; on the other one the trees closed in overhead: every endeavor was made to avoid felling any trees whose trunks did not come within six feet of the centre line of the ray; thus very few fine trees were cut down. The forest was in places interlaced with dense masses of creepers, and heavy storms of wind sometimes caused these creepers to drop down and shut up the ray. On these two lines there fell about four miles of forest, most of it belonging to tea estates; as the forest was close to Dibrugarh, compensation was demanded for the timber cut down. The satisfactory settlement of these claims took up a great deal of my time. On the branch series to Jaipur many miles of line passed through tea estates, and I am glad to say that the ray-cutting parties were not interfered with in their work, Mr. O'Sullivan taking special care to do the least possible damage.

4. The preliminary work already done on the Jaipur Series, detailed in paragraph 2, had been executed by Mr. O'Sullivan. To carry up this triangulation to the side, whence it was to be extended direct on to the Naga Hills above Jaipur, required the construction of five post stations, the final carrying of six rays of which the trial lines had been run, the cutting of three new lines, and the observing the angles of the triangulation. To Mr. O'Sullivan was assigned this work. He broke ground on the 10th November, and was employed on this series throughout the whole field season, except for a week, when he observed at Dibrugarh the angles to the Nari H. S. and Dipa H. S. of the principal series.

The extension of the principal series up to Poba was entrusted to Mr. McCarthy, who left Dibrugarh with his detachment on the 10th November.

5. I started from Dibrugarh for the Khalkata Station of the principal series on 12th November, observed principal angles at three stations, and angles to hill peaks at two stations; then I went to Poba, whither I had sent the writer of the party (Baboo Zuhur-al-Islam) and a detachment of men, with instructions to make a road from the Mekla Station to the Poba Station and begin the line-cutting of the preliminary series between Poba and Sadiya. When I reached Poba, I found that considerable progress had been made. The preliminary series was carried up from Poba to the line Dibangmuk—Napsur by the 1st January 1877. A trial line was also cut between Sadiya and the Dikrang martello tower, the final ray being afterwards cut by the Topographical Survey Party under Lieutenant Woodthorpe, R. E. During November and December I observed from four stations to all the hill peaks visible from those stations. I had very bad luck in my work to hill peaks, considering the time I devoted to it. I made many fruitless journeys, and lost many days in my endeavors to get angles to the snowy ranges from stations favorably situated for the intersection of the peaks; not that there was any lack of splendid days for peaks during the season, but I got so few chances when I was available for the work.

6. One of the lines cleared by Mr. O'Sullivan passed through a heavy forest in which a gigantic India-rubber tree took a party of 20 men nearly two days to fell, and then it took 10 men a whole day to settle down the debris. Big trees are rare in the plains of Upper Assam—only one other was met with this season, it was on the line Sadiya—Manabum H. S.; luckily the trunk was a mere shell, for it measured 43 feet in girth at 4 feet above ground.

7. In January I sent eight men with an elephant to make a foot-path of about 4½ miles along the bank of the river between two stations; after four days the men returned and reported the path cut; also, that a great deal of very heavy cane had been met with through which the elephant could make but little way, and the path would speedily close up. A week passed, and I had occasion to send along this path a signalling party, and though the men started early, they did not get to the station 4½ miles distant till the following morning. Some days afterwards, two of them returned in a boat for provisions, and started back by the foot-path in the forenoon; but they again past a night in the forest. This incident serves to show how seriously a cane jungle hinders our progress; the natives with their bare legs are obliged to go through it very slowly, and deal with it cautiously.

8. At one station, with a party of 10 men I built a scaffolding of 75 feet in height in three days. This lofty field observatory is a very stiff and substantial structure, 8 feet square at top, and although bamboos and cane (of which it is constructed) rot with surprising rapidity in Assam, I hope that it will need but little repair next year to make it answer its purpose.

9. In the narrative report for the year 1875-76, it is stated that the "Abar" tribes objected to the occupation of a couple of peaks (Dipa and Nari) on the outer ranges north of the Brahmaputra river, one of which was intended to be a station of the principal series. Arrangements were made for a force of 100 men of the 44th Sikh Light Infantry to escort the Survey Party to the hills. Our orders were to confine the survey work to those two points, not to make excursion for sketching purposes, and, as far as possible, to avoid all villages.

The 15th of January was the date fixed for the small expedition to leave Dibrugarh; it was estimated that the troops would be absent one month.

We reached the top of the "Dipa" hill on the 18th January. It was cleared sufficiently for the trigonometrical work, a pucka station was built, the angle required was observed, all possible sketching done, and we left for "Nari" hill on the 21st January.

Dipa hill is nearly 3,000 feet high; we had to find our own way up it. The spur selected to ascend by turned out to be a very narrow, serrated ridge, and very steep, and had it not been for the dense forest, I much doubt whether we could have got up the hill by that spur. The station was about 4 miles from our camp on the Diman river. The trees on the hill top were festooned with masses of great creepers, many of which yielded a good supply of water; nearly a pint oozed out of a yard's length of one of them.

Major Clarke, B. S. C., Deputy Commissioner of North Lakhimpur, kindly arranged for some road cutting, which proved of great service to us.

To get to the Nari hill, we waded for 12 miles up the Dipi river, thence cut a road ¾ of a mile long to the foot of the hill, and struck a wild elephant track which led nearly to the top. The station was about 6 miles from the camp on the Dipi river. The Nari hill is nearly 3,000 feet high, and easy of ascent. The summit was cleared, and the station built by 30th January.

Shardon Rai Chand Bahadur, Seristadar of the Court at Dibrugarh, who was detailed to accompany the party, gave us most energetic aid, and through him I got the services of 25 "Miris" to help me to clear the Nari hill.

I encamped on the hill top from the 30th January to the 6th February. The weather was very rainy, and we were visited by some appalling thunder-storms. We heard on two days the volley firing of the squads at rifle practice on the ranges at Dibrugarh, distant 25 miles as the crow flies. The observations were finished on the 12th February, and then the troops returned to Dibrugarh.

To Major Robertson, B.S.C., my best thanks are due; he gave me every help, the arrangements were most convenient, and my progress greatly facilitated; not the slightest hitch of any nature occurred.

Colonel Nuthall, B. S. C., Commanding at Dibrugarh, was most kind in giving us every assistance; he came on one occasion to "Dipi Muk" to meet us. The jungle at the foot of the hills is tremendous.

The hills are clothed with magnificent timber, and we saw many fine rubber trees which had never been tapped. The formation of the outer ranges is of coarse-grained sandstone, soft and friable. The country between the outer and the first high range is full of low hills heaped together in the wildest confusion, showing hundreds of small precipices of various shades of red, white, and brown. From the Dipi and Nari hills only a few tiny patches of cultivation were visible. The "Abors" did not put in an appearance, and, excepting a few well-known men, we saw very few of them. A sketch was made of 100 square miles of plain country and 300 square miles of hills, hitherto unsurveyed. A pucka platform was built near the mouth of the Dipi river, and fixed by intersection from the Nari and Dipi hill stations.

11. From the 9th to 31st March, rain fell on every day except two; excepting those days, the tents of the party were never dry. The greater part of the rain fell late in the evenings, yet we had not altogether twelve hours of sunshine after the 9th March if we leave out the two days before mentioned. Fortunately most of the lines of the series being short, it was found that by taking special precautions in setting the signals, there were often short periods during the day when the gleam from the silvering of the heliotropes could easily be seen in the telescope, despite the absence of sunshine. Thus by watching my opportunities I managed to observe angles from 13 stations during the month. Mr. McCarthy carried two trial rays, two final rays, and built one post station in March. He was not well during this month, yet he worked very hard: one day a tree accidently dropped on to his head, and I am sorry to say he was confined to his tent for three days in consequence.

The filling of the nullahs, the rain, absence of sunshine, and appearance of myriads of leeches, seriously impeded progress and caused the line-cutters to suffer severely. The work on the delta of land between the Dibang and Brahmaputra rivers was most difficult, the lines in the forest about the Dibang muk station rarely progressed as much as 400 yards a day; so dense is the jungle and so numerous are deep nullahs choked with the heaviest growth. The Dibang-muk station stands in the depth of the forest; around the station a considerable area had to be cleared to admit the sun to the station so as to allow of signals being shewn during the greater part of the day: on to this station, converge 5 lines. A visit to this place would enable one to form a good idea of the enormous amount of labor required on parts of the preliminary series. The station is prettily situated, and the platform is high enough to give glimpses of the river through the gaps, and of the snowy ranges peeping over the trees; sometimes the lines are filled with very beautiful sunlight effects.

12. On the 1st of April I crossed the Brahmaputra in a heavy gale of wind, a great storm raged over the Dihang river, and the phenomenon of a water-spout was witnessed. On the afternoon of the 2nd April the observing overtook the work of the preliminary series, and I had made my arrangements to go to Sadiya, when a khalassie came in to report that at noon of the preceding day our 80-maund boat was lashed alongside the bank at a spot about 30 miles below my camp (Dibang-muk), when a great wind carried off the heavy roofing of the boat and then the waves swamped and sunk the boat in deep water. On board was a tin-box containing the duplicate set of computations of the recess season 1876, together with other papers. Taking with me a few men, I started down-stream by boat at midnight of the 2nd; the night was rainy and pitch dark, and we had several escapes from snags, so we stopped on reaching the rapids below Poba stockade and waited for the dawn of day. On the evening of the 3rd the sunken boat was dragged out of the deep water, but in the night the river rose, ran like a sluice, and the boat broke loose and filled with sand. Our efforts to move it on the 4th were ineffectual, so I left the spot on the 5th and reached Sadiya on the 6th, having lost four splendid days on my trip. Three weeks afterwards, a "Miri" got up the tin-box with a spear, and I was glad to find that the contents had suffered no material injury.

13. Lieutenant Woodthorpe, R.E., in charge of the Topographical Survey Party working in the Singfu country north east of Sadiya, had selected a trigonometrical station on the Mánabum hill height about 600 feet, 18 miles east of Sadiya, which it was necessary to incorporate with the principal triangulation. I found the station at 112 feet above the top of the hill in the branches of a gigantic India-rubber tree. The station is 4 miles east of the Tengapani, a river full of fine rapids which can only be shot in small canoes. The morning I visited Mánabum was rainy, the leeches were most formidable and indescribably numerous, especially where the path had been cut through bamboo forest. One man was lame for a week from the leech bites of that morning.

On our return from the hill the sun was shining fiercely, and not a leech could be seen. The natives smear over their legs a mixture of tobacco juice and lime which gives protection against the leeches, but in the wet jungle the stuff quickly gets washed off.

I met Lieutenant Woodthorpe, R.E., on the Tengapani river, to arrange with him the connection of our respective triangulations. I got back to Sadiya on the 20th April, completed the angles at 3 stations, and opened out the rays to the Mánabum hill station by the 29th April. Only one angle was measured to the Mánabum hill station on account of the unfortunate premature return of my signaller from that place; but Lieutenant Woodthorpe got a few observations at Mánabum to my two stations in the plains: thus a preliminary value for the Mánabum hill station has been obtained.

At Bhati Sadiya station on the 29th April I got a touch of the sun and was seized with severe illness, and consequently getting to the Dibang-mukh and Napsur stations and observing the remaining angles at those places, gave me some trouble.

14. Lieutenant Woodthorpe, R.E., was journeying to Dibrugarh after the close of his field season's work when he heard that I was ill. He came to Napsur station and stayed with me till he had seen me through my remaining work on the principal series; and had it not been for his kindness in staying with me, I doubt if I could have completed it.

15. It was unfortunate that so few angles of the Jaipur Series were measured as the work progressed, it resulted in our being unable to finally measure all the angles of the series by the close of the field season. Mr. O'Sullivan placed signallers on "Hilika" station, who were threatened by the "Nagas" and turned off the hill, so I applied for and was given a police force to prevent further annoyance. Having recovered somewhat from my sickness, I left Dibrugarh for Jaipur, accompanied by Mr. McCarthy, on the 7th May, cut the line Timolikhat to Hilika, visited Deohal hill on which Mr. McCarthy erected a 50 feet bamboo scaffold, completed the observations at Hilika hill station, Timolikhat station, and all the angles but one at the Bamonikora station, by the 14th May.

May was a very wet month, the country got deeply flooded; it once took us 7 hours to wade along 5½ miles of path. Following me on that occasion, were 3 elephants very lightly laden, one of which fell into a hole and would have drowned but for the promptitude of a khalassie who got down and cut the girth ropes with his "dao" On the night of 16th May I became very ill and rapidly got extremely weak. It rained almost incessantly from the evening of the 16th to the 20th May; on the latter day the ground on which my camp stood was swamped, and I was carried to the Madarkhat station. There I met Mr. McCarthy, who had been hard at work, carrying a line through the flooded jungles. After making an effort to observe angles at the Madarkhat station, I made over the work of observing to Mr. McCarthy, who got measures of the angles at Madarkhat station on the 21st May. He closed work and marched into Dibrugarh on 23rd May. After the 8th May, Mr. O'Sullivan got angles at 2 stations and observed a set of vertical angles at the Madarkhat station; he marched into Dibrugarh on the 22nd May.

The weather from the 16th to the 25th May was simply dreadful, the large amount of rain falling fairly stopped our work.

16. The whole party left for Gauháti by steamer on the 26th May. After settling the affairs of the party, I took leave on medical certificate on the 10th June. Messrs. O'Sullivan and McCarthy went into recess quarters at Shillong.

III.—Extract from the Narrative Report, dated 20th September 1877, of H. Beverly, Esq., Surveyor, 1st grade, Officiating in charge of the Burma Party.

2. The party continued in recess quarters till the end of October engaged in the computations of the previous season. Mr. W. Beverley, in charge of the party, returned from privilege leave on the 28th October, and after taking over charge he proceeded on the 7th November to Rangoon, to resume field work, leaving Messrs. Mitchell and Collins to follow him by the next steamer. He remained in Rangoon from the 8th to the 17th November, organizing the field establishments and completing the charts and computations of the late recess.

3. During season 1875-76 the field work of the party was as follows:—

First.—A chain of secondary triangles (designated "Myanaóng and Cape Negrais Triangulation"), emanating from the Eastern Frontier Series, was carried south, by Mr. W. Beverley, through the Henzadá district, and terminated for the season on the side Gnaw-Lekho, in the Bassein district. A second chain (designated "Prome, Thayetmyo, and Tonghú Triangulation"), also emanating from the above series, under Mr. J. Low, was carried north towards the frontier, and terminated for the season on the side Minúkídong-Menbhadong, in the Thayetmyo district.

A third chain (designated the "Rangoon and Coast Triangulation"), emanating from sides of the Eastern Frontier Series in the Shoaygheen and Amherst districts, was commenced the previous season, and the work was finally brought up last year to the side Mengálón to Lekheik.

4. During the field season 1876-77 the programme was as follows:—

Mr. W. Beverley to continue the chain of triangles towards Cape Negrais, and also to determine the positions of the towns of Henzada and Bassein. Mr. Low to continue the Prome, Thayetmyo and Tonghú Triangulation in an easterly direction as close to the frontier as practicable.

Mr. J. W. Mitchell was ordered to take up a chain of triangles from the side Myáyábengkyó-Théyékhú of the Eastern Frontier Series (which was approximately laid out last field season) in a northerly direction, through Tonghú till the frontier was reached, and then to proceed westward and connect with Mr. Low's triangulation. Mr. D. J. Collins to continue the Rangoon and Coast Triangulation towards the Kristna Shoal light-house. But as this work could not be resumed till the country was dry, about the beginning of January, he was ordered to determine the position of the small town of Minjí to the south-east of Myanaong, and to complete the triangulation to determine Henzadá, thereby relieving Mr. Beverley, who could take up the extension of the first chain of triangles.

5. Mr. Beverley was engaged on the Henzada Branch Series, where he took observations at five stations and at one hill station of the main triangulation, thereby determining the positions of several buildings in Henzadá. This work occupied him nearly to the end of December. He next took up the extension towards Cape Negrais. Mr. Beverley carried this triangulation 36 miles in a direct line, bringing down the triangulation to the civil station of Bassein, and likewise determining the positions of some important points in that station. He had unusual difficulties to contend with during the field season. The course of the Cape Negrais Triangulation is selected with one flank on the low hills on the Arracan Yomas, and the other flank in the plains, to avoid enhanced expense and delay had the triangulation been wholly in the plains or on the uninhabited hills. In the plains advantage is taken of isolated pagodas on one of the platforms or ramps of which the station is selected, thereby raising the station 20 to 30 feet above the surrounding country. The hills in the Bassein district are uninhabited, and are never visited by any of the inhabitants of the plains to the east. They are also of almost equal elevation, flat-topped and covered with a dense forest; hence the difficulty in finding the particular hill selected in a large block: to which is added the unwillingness of the villagers to leave their homes and be away at night. The difficulty is to retain them for more than a day or two. The hills generally require extensive clearing before they can be used for trigonometrical purposes. In the plains also great difficulty is experienced in carrying lines through swamps. Mr. Beverley lost much valuable time owing to these swamps and the low forest-clad hills. Mr. Beverley closed work on the 21st April and returned to recess quarters at Moulmein on the 2nd May. On the 18th idem, having obtained furlough, he made over charge of the party to me.

6. Mr. J. Low, Surveyor, 2nd grade, rejoined from four months' private leave at Rangoon on the forenoon of the 20th November, having received instructions to extend his last season's triangulation from Thayetmyo along the frontier towards Tonghú; he left Rangoon by steamer and arrived at Thayetmyo on the 29th November.

7. Mr. Low extended the secondary triangulation 11 miles by six stations, forming two figures, terminating the series for the season on the Pegu-Yoma mountains. Much of his time was taken up in marching, and he had to visit his stations twice or three times—once to select the station, and a second time to observe the angles from it. In a wild country like Burma, with flat-topped hills of almost equal elevation, covered with dense forest, far removed from the nearest villages and nothing to distinguish one hill from another, it is very difficult to select stations. The Surveyor finds it impossible to send any one of his establishment on this task merely by pointing out the hill to him; he has to visit the hill himself, select and clear it, and return to take observations to it. Mr. Low has also determined a few peaks on the Arracan and Pegu Yomas and a few other points, the heights of which he has also determined. I think Mr. Low's out-turn of work is satisfactory.

8. Owing to the unhealthy nature of the country Mr. Low worked in, his health has suffered; he had to leave on medical certificate for six weeks during the field season, and since his return to recess he has suffered repeatedly. He has been under the Civil Surgeon's treatment for some time, and is at the present moment far from well.

9. Mr. J. W. Mitchell, Surveyor, 4th grade, left Moulmein for Rangoon on the 9th November. On the 13th he started for Tonghú to take up the triangulation to Tonghú from a side of the Eastern Frontier Series, some of the stations of which had the previous season been prepared by him. Mr. Mitchell extended the triangulation to the Burmese frontier, a distance of 56 miles, and determined the positions of three points in the station of Tonghú. By the middle of February there was a break of only 50 miles in the triangulation between the work of Messrs. Low and Mitchell, which Mr. Beverley considered would require one Surveyor to complete during the remainder of the field season with favorable weather. He, therefore, requested Mr. Low to form the connection and Mr. Mitchell to return and join him, to assist in the Cape Negrais Triangulation and to determine points in the station of Bassein. Unfortunately, Mr. Low was just then taken ill, as previously stated. On his return from sick leave, Mr. Low was only able to complete the angles he had left unfinished. Hence there remains the break of 50 miles between Mr. Low's and Mr. Mitchell's triangles, which, it is hoped, will be completed next field season. Mr. Mitchell meanwhile left Tonghú for Bassein, and arrived at Rangoon on the 15th March. There he waited a few days to entertain some men, and arrived at Bassein on the 22nd March. Mr. Mitchell observed both horizontal and vertical angles at two stations in the town of Bassein, and five in the Cape Negrais Triangulation. Mr. Mitchell states that his stations on the Tonghú Triangulation were all in uninhabited hills, and he experienced great difficulty in visiting them. Mr. Mitchell closed work on the 22nd May and arrived at Rangoon on the 24th May. At Rangoon he was attacked with cholera, which weakened him considerably, thereby preventing his return to recess at Moulmein till the 13th June. In Moulmein, too, Mr. Mitchell has suffered from illness. He was attacked with dysentery some time ago, and though under the Civil Surgeon's treatment, he has not yet quite recovered from it. His progress, I think, has been satisfactory.

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7. Mr. Low extended the secondary triangulation 44 miles by six stations, forming two figures, terminating the series for the season on the Pegu-Yoma mountains. Much of his time was taken up in marching, and he had to visit his stations twice or three times—once to select the station, and a second time to observe the angles from it. In a wild country like Burma, with flat-topped hills of almost equal elevation, covered with dense forest, far removed from the nearest villages and nothing to distinguish one hill from another, it is very difficult to select stations. The Surveyor finds it impossible to send any one of his establishment on this task merely by pointing out the hill to him; he has to visit the hill himself, select and clear it, and return to take observations to it. Mr. Low has also determined a few peaks on the Arracan and Pegu Yomas and a few other points, the heights of which he has also determined. I think Mr. Low's out-turn of work is satisfactory.

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12. Mr. Collins during the next two months protected and transferred to the care of the local officials six principal stations of the Eastern Frontier Series. Besides these, he visited Yongdong near the town of Prome. This station he reported had been removed, and a large hole indicated the site of the station. He also attempted to visit the trigonometrical station of Moditong, in the centre of the Arracan Yoma mountains, but the coolies refused to go. He returned to Rangoon by steamer on the 16th March to resume the triangulation along the coast. He was ten days in Rangoon entertaining men and waiting for his theodolite. On the 27th he left by boat to visit the two stations of Lekheik and Mengalon to start the Coast Triangulation. He was only able to visit these two points and construct a ladder up the former, when, on the 10th April, he was taken ill and returned to Rangoon, where he obtained a medical certificate from the Civil Surgeon and closed work for the season. Mr. Collins was on three months' privilege leave, from the 13th April to the 13th July.

16. There now remains a break of 50 miles in the triangulation along the frontier, which will probably be completed by one assistant next field season. The Cape Negrais Triangulation of 80 miles to the Alguada light-house and the extension to the Krishna Shoal light, about 70 miles, are likely to occupy two officers two seasons.

17. The Krishna Shoal light was washed entirely away during the present monsoons. As this point is important for shipping, a new structure will probably be erected by the time the triangulation is brought down to it.

21. The area triangulated by this party during season 1876-77 is 4,615 square miles, at a cost of Rs. 38,517-14-3, giving a rate of Rs. 8-4-8 per square mile.

IV.—Extract from the Narrative Report, dated 1st October 1877, of Captain J. Hill, R.E., Assistant Superintendent, 1st grade, in charge of the Eastern Frontier Series.

2. On returning to Bombay from furlough to Europe, and receiving orders to assume charge of the Eastern Frontier Series in Burma, I proceeded at once, *viâ* Calcutta and Moulmein, to Tavoy, where I landed on the 9th of last March, and where elephants sent by Mr. H. Beverley, were awaiting me. The head-quarters camp happened to be only about a week's march from Tavoy. I found it on the 16th March just arriving at Toungthúnloun H. S., and on the following day I assumed charge of the Party.

3. When Mr. Rossenrode was retiring from Government employment, Mr. H. Beverley received the officiating charge of the Party and retained it until my arrival. I then found his observations were almost completed for the season; so as it was too late to detach him for other work, I decided on allowing him to finish what he had carried on so far. The whole credit of the field season's principal operations therefore belongs to Mr. H. Beverley, and as my information regarding what took place before my arrival has been chiefly derived from him, he has at my request drawn up the following narrative statement of the season's work:—

(*b*). "On the 1st November this Party comprised three Surveyors, *viz.*, myself, Mr. J. C. Clancey, and Mr. J. O. Hughes. I purposed re-uming myself the final operations suspended on the setting in of the rains, about 60 miles south of Moulmein; while Mr. Clancey should extend the approximate triangulation, which last year closed with the Myándoung figure in the Tavoy District. Mr. Hughes with a small party I wished to employ on secondary operations, determining the positions of Phavátounzú (the Three Pagodas), the town of Yeh, &c. All my arrangements were in a measure temporary. I was informed that Captain J. Hill, R.E., was appointed Mr. Rossenrode's successor, and would arrive in India about the end of January. I presumed he would, probably within a month of that date, join the Party, when as a matter of course the arrangements would have to be altered. On his assuming charge on the 17th March, he considered it unnecessary to alter existing arrangements for the short time that remained for field operations; hence the above arrangements continued to the close of the season, and at his request I continued taking final observations for the remaining three stations.

(*c*). "Mr. Clancey was requested to leave Moulmein by the Tavoy steamer on the 7th November, his camp having left overland for Tavoy on the 24th October to await his arrival. Mr. Hughes continued with me to bring up the office work till the 15th November: he left Moulmein on the 22nd idem to take up secondary observations. During the first week of November the signal parties were sent to their respective stations, some overland, and others by boat. At the same time the tindal with fifteen men was ordered to clear the path from the Moulmein and Amherst road, the first station of observation. A week later, on the 14th November, I despatched the main camp, theodolite and elephants for the above station, where they arrived on the 28th idem. A few days later, after despatching the preliminary chart and records to head-quarters, I left by boat for Keoktagá, arriving at that station two days after my camp.

(*d*). "During the observations at this and the next station I noticed certain discrepancies in the horizontal readings of the 24-inch theodolite, which I could not for some time account for, the change affecting only one station at a time occasionally. I subsequently found they were caused by a slight lateral motion on the telescope, from its revolving unevenly in the Ys. As I did not know how to remedy this, without perhaps putting the instrument out altogether, and as only occasionally these differences occurred, I left it for Captain Hill to rectify on his arrival.

(*d*). "Consequent on the paucity of villages in the tract of country wherein our operations lay this season, and the unwillingness of the inhabitants to leave their homes for more than a day or two, I deemed it expedient to entertain a large number of men in excess of our usual numbers for the cutting of roads, transporting of baggage of signal parties, &c. I also purchased large quantities of rice and paddy for the camp, enough for a supply for two months, by which time I expected to enter the inhabited tracts of the Tavoy District. A portion of these provisions was transported by boat to the village of Onbengkweng, where rice could not be purchased except at the exorbitant rate of about 7 seers per rupee. These arrangements certainly increased the working expenses of the Party, but they obviated failure. The number of villages met with on the line of march, throughout the season, was only 23, including the town of Yeh, and but four large villages, the rest being hamlets of from 4 to 8 or 10 huts, from which we could not expect labor or provisions to meet the demands of such a large camp.

(*e*). "The field season lasted five months; of this, 80 days were employed by the main camp exclusively in marching, there being no direct route from station to station, the time occupied in marching to each station

being from 3 days the least to 10 days the largest number of stages; this could not be helped in a country which is almost entirely uninhabited, and circuitous routes had to be taken. I was fortunate this season in not being delayed much more than a fortnight from hazy weather, which in former seasons generally deterred operations for a considerable length of time. A party of 15 men under the tindal, assisted with such coolies as could be procured from the villages, was employed throughout the season to precede the main camp, clearing the path and making it passable for the large theodolite and for elephants, a task accomplished with the least possible delay to the camp."

4. The foregoing statement refers principally to Mr. Beverley's own operations. His remarks upon the instructions he gave to Messrs. Clancey and Hughes, and the manner in which his instructions were carried out, are as follows :—

(*a*). "Mr. Clancey was deputed to extend the approximate triangulation; he left by the steamer of the 7th November, and arrived at Tavoy on the 8th.
Mr. J. C. Clancey.

(*b*). "At the close of last field season, the approximate triangulation had been brought down to the Myándoung figure, of which one station had still to be selected and one other built: two more stations in advance had been visited, and one of them, Toungshún, built. Mr. Clancey was requested, before commencing work, to visit Toungshún and another hill near Tavoy, and thus proceed upwards to the base of his operations, by which means he would obtain a very good knowledge of the country. He was also requested, if possible, to keep on to the main land and avoid visiting the islands, which would, I considered, be a source of considerable delay and expense.

(*c*). "By the 27th January Mr. Clancey had laid out a satisfactory triangulation, comprising (1) the completion of the Myándoung figure by the selection of one new station; (2) the completion of a quadrilateral which had been partially selected last year; and (3) a hexagon round Toungshún H. S. of the previous season's work. Two of the stations of this last figure were on islands, known as the Moscos, averaging about 20 miles from the opposite mainland stations.

(*d*). "Mr. Clancey's reasons for making use of the islands were, that he found it impossible to continue the triangulation on the mainland, since he could not get suitable sites on the frontier range, and the country to the east was uninhabited, and under these circumstances I think he was justified in carrying the triangulation partly on the mainland, and partly on the islands.

(*e*). "Mr. Hughes left Moulmein by boat on the 22nd November for Amherst, and thence by land to Yeh, from which place he was requested to cut a road for the 24-inch theodolite and the elephants to Sedoung H. S., a road which Mr. Rossenrode had found it impossible to cut the previous year, through the duffadars he repeatedly sent with that object failing each time on account of the difficulty in getting the villagers to work. From Yeh to Sedoung, a distance of nearly 30 miles, the country is uninhabited, with the exception of a few huts about half-way, and coolies could not be procured. Mr. Hughes completed this task by the middle of December, not, however, without my having to send to his assistance all the men detached from the main camp for general road-cutting.
Mr. J. O. Hughes.

(*f*). "The secondary work upon which Mr. Hughes was afterward employed was the determination of the position of Phayátounzú (the Three Pagodas), the well-known boundary between Siam and Tenasserim; also the determination of the position of the town of Yeh, and other points; which work, I expected, would employ him to the middle of February, when he was to join the main camp about the time of Captain Hill's arrival. I left it optional with him to determine the position of Phayátounzú either by a series, or directly from the principal stations, if visible. Mr. Hughes adopted the latter plan, and completed the necessary observations at one of the two principal stations chosen for the purpose. Unfortunately, when he arrived at the second, bad weather had set in, and long sights could no longer be observed. He remained on the spot as long as his provisions lasted, and then finding the haze did not clear, left the place and joined my camp on the 2nd March. Mr. Hughes was next detached to determine the position of Onbengkweng village and two pagodas in the Myándoung figure, which he accomplished and joined the main camp on the 17th March."

5. After Mr. Hughes had joined the main camp, as above stated by Mr. Beverley, I detached him—(1), to select and build a secondary station in a good position in the town of Tavoy; (2), to help Mr. Clancey by clearing two hill tops which Mr. Clancey had fixed upon as sites for principal stations; (3), to place a secondary station upon the well-known peak and land-mark Nwúlabo (Ox's Hump). He selected and built the station in Tavoy, and made some progress with the clearing of the hill tops, when it became necessary, in consequence of the conclusion of the principal observations and the arrival of the main camp at Tavoy, to call in both him and Mr. Clancey. They reached Tavoy on the 22nd April, and the whole party (excepting the elephant establishment and some other men I thought necessary to leave behind) started for Moulmein on the 24th April.

6. During the recess the party has been chiefly employed in computing out the work done during the field season. A considerable amount of time has also been taken up in classifying and reducing to order the records of the party. The transfer of the principal stations in the Amherst district to local official protection, which was stopped by the late Officiating Deputy Commissioner of the district, has been proceeded with, and, owing to the willing co-operation of the present Deputy Commissioner, has been almost completed, only one station now remaining to be transferred. The performances of the 24-inch theodolite having been complained of by Mr. Beverley (*vide* paragraph (3) (*d*) I examined it, and finding the Ys not quite parallel to each other—a defect I had not the means of remedying—I sent it on the 10th July to the Mathematical Instrument Department, Calcutta, for repair. Mr. Beverley was quite right in bringing to notice the irregularity in the working of the theodolite, but I believe he was mistaken in thinking it was a new defect; for Mr. Clancey, who acted as Mr. Rossenrode's recorder, informs me that Mr. Rossenrode used to suffer inconvenience from irregularities of reading similar to those described by Mr. Beverley, and I find that, judged by the average triangular error and probable error of angles, the quality of Mr. Beverley's observations appears to be much on a par with Mr. Rossenrode's averages for the preceding three seasons: so that the instrument would not seem to have recently undergone any sensible alteration. On the 1st September, Mr. D. J. Collins, Assistant Surveyor, 4th grade, joined my party from the Burma party, Mr. Hughes being at the same time transferred to the latter party in his place.

7. During the field season observations were taken at twelve principal stations, all of which were duly closed except the initial ones of next season, and at six secondary stations. The average cost of the season's operations, as calculated by the departmental method, is Rs. 11-13 per square mile triangulated.

8. The several operations of the party have not been uniformly successful during the past season. The principal series has been well conducted by Mr. Beverley. His preliminary arrangements for taking the field were good, and proved quite successful. The quantity of principal triangulation completed only falls short by 558 square miles of Mr. Rossenrode's yearly average since the resumption of operations in 1873, and its quality, as already stated in paragraph 6, accords very well with that of Mr. Rossenrode's work during the same period. The area of the secondary and minor triangulation is the largest which has been obtained since the resumption of operations, and although the area of the principal triangulation does fall short of the average of the preceding seasons, that fact is accounted for and justified by the shortening of the time suitable for observations as the series proceeds southwards. No useful purpose seems to be subserved by trying to continue principal observations in Southern Burmah beyond the early part of April, by which time the last break in the hot weather haze may be expected to have taken place. Work was, therefore, closed at the time already mentioned, and I consider the out-turn very creditable to Mr. Beverley, especially as, owing to the great length of the difficulties and circuitousness of the routes, he was only able to spend 44 days in actual observing out of a field season of 156 days' duration. It is to be regretted that Mr. Hughes failed to determine the position of the well-known "Three Pagodas" which are situated on the road from Moulmein to Bangkok at the exact spot where it crosses our frontier. Although the pagodas are now in ruins, as a boundary mark they are very important, and their position ought to be fixed at the first available opportunity.

V.—Extract from the Narrative Report, dated 21st September 1877, of Captain M. W. Rogers, R.E., Offg. Deputy Superintendent, 3rd grade, in charge Jodhpore Series.

The party took the field in October 1876: the first detachment under Messrs. Price and Torrens left on the 16th October, and marching direct to the series, commenced work on selection and building. The main party left Aboo on the 23rd October, and marched to Chachra, in Thar and Párkar, and thence to Rojhrá II. S. of the Karáchi Series, one station of the initial side of the new Series, "The Eastern Sind" principal observations were commenced there on the 20th November: from that date the observations were carried on continuously through the Thar and Párkar district of Sind, the Khairpur State, and into Jeysulmere, and were closed at Dhanono II. S. on the 18th March.

The weather was, on the whole, very favorable for observations until March, when, as usual in the desert, high winds and dust-storms commenced and made observing difficult and tedious. The following is a general statement of the season's work: 96 angles were observed at 28 principal stations, forming 4 hexagons, 2 quadrilaterals and a portion of another hexagon, fixing 26 new principal stations, embracing an area of 2,455 square miles, and extending the series 125 miles along the meridian. An azimuth was observed at Malár II. S. to two circumpolar stars. The approximate Series was extended north 98 miles. The position and height of the town of Umarkot were fixed, and 28 Revenue Survey stations were identified and fixed in height and position. Mr. Price was in charge of the approximate series: he selected 21 and built 10 principal and 7 secondary stations, completing the selection of the Eastern Sind Series. He, as usual, worked well and steadily, and accomplished a good amount of work, notwithstanding the drawbacks of an unfavorable country. Mr. Torrens took up the building on the principal series and completed 19 stations: he then closed 16 pricipal stations, and, in addition, he identified and marked a large number of Revenue Survey stations, and did a considerable amount of secondary triangulation to fix them.

The building operations of these desert series, involving in most cases the arrangements for making bricks, and in all cases a large amount of trouble and arrangement for the transport of bricks, stones and lime to the various sites from long distances, are of an unusually arduous nature; and I was much pleased with Mr. Torrens' exertions and general work, which fully entitle him to his promotion whenever the state of the Department permits. Mr. Prunty accompanied me as recorder during the whole of the observations, and after their completion, he closed seven stations of the principal series: he has worked very well, and is in all respects a good and useful assistant. The health of the party during the whole season was very good.

The country through which the series passed this season is, if possible, a more desolate tract of desert than any met with on the Jodhpore Series. Towards the south, in the districts of Thar and Párkar, the country is a succession of narrow sand-hills, sometimes of considerable height, running from south-west to north-east in perfectly parallel lines: they are higher, and the ridges closer together, than in Rajputana, and their sides are much more abrupt, and are channelled into ravines by the action of rain, and are covered with low thorn jungle. This makes travelling very tiring and tedious, as in marching, the village tracks had to be followed, and long detours made. This combined with the heavy sand and the continual up and down hill, caused the marching between stations to take up a considerable amount of time, 10 miles being a heavy march for loaded camels.

For about 50 miles along the western side of the series the country was inundated, and a vast expanse of water stretched as far as the eye could reach. The town of Umarkot, when

visited, was surrounded on two sides by water, which came up to the base of the fort. In the north of Thar and Párkar, and in Khairpur, and the western portion of Jeysulmere, a new phenomenon is met with. This is the "Draeus" or expanses of shifting sands, many miles in extent, and scattered here and there amongst the desert sand-hills, which are comparatively fertile, inasmuch as they are bound together and partially covered with coarse grass and stunted shrubs. These "Draeus" have no vegetation, and their surface is continually changing, and the sand in them is in one place scooped out into funnel-shaped hollows, and in another thrown up into beautifully-rounded hills. They were seldom crossed, but when necessity compelled a march over one of them, the road had to be inspected and prepared beforehand; and five miles was a fatiguing march. Curiously enough, in spots in these "Draeus," there are wells of water on small pieces of hard ground, which seem to be spared by the overwhelming sand, and in these wells the water is invariably good. The "Draeus" are very numerous, from about 26 North Latitude, and extend northwards some 75 miles. They impoverish the already sterile country, and I am inclined to think that the acme of desolation is reached in Eastern Khairpur and Western Jeysulmere. There are no crops, and the people live nearly entirely on milk in various forms, aided by a little "bajri" and "mot" imported from Sind in exchange for sheep. The inhabitants say that the "Draeus" travel gradually northwards, but very slowly. The summits of these "Draeus" rise to a considerable height, in many cases overtopping the sand-hills; and it became a matter of considerable difficulty to arrange the series, so as to avoid the stations falling on them. Notwithstanding all the care given to this, two stations had to be placed on them; every attention was given to building these stations with all precautions for stability, but I am doubtful if they will remain for long. The villages are of the same description as those met with in the other portions of the desert; the majority of the houses are merely wigwams of brushwood, a house with mud walls being a rarity, and brick and stone almost unknown. With the exception of Umarkot there was no place in the series worthy of the name of a town. The villages are nearly, without exception, built on the summits of sand-hills, and very often at some distance from their wells, which are, of course, in the hollows between the hills. The reason for this custom seems to be, that in the cold weather the tops of the sand-hills are considerably warmer than the valleys, where the cold is sometimes very great. The party experienced considerable trouble from the difficulty of procuring drinking water, especially on the eastern side of the series, near junction of the four States of Marwar, Jeysulmere, Khairpur and Thar and Párkar, where there is a tract of country about 30 miles broad by 40 long without any drinkable water, and it was with much difficulty that the necessary supply for the camp could be obtained.

Most useful assistance was rendered to myself and assistants in Thar and Párkar, Khairpur and Jeysulmere, where every thing possible was done by the local authorities to help my work, and my best thanks are due to Captain Crawford, the Superintendent of Thar and Párkar, His Highness Ali Murad of Khairpur, and the Jeysulmere Durbar. The total cost of the party for 1876-77, was Rs. 37,764-10-11, or Rs. 15-6-1 per square mile for the principal triangulation, or Rs. 14-8-10 for the whole triangulation. During the recess season, the computations of the season were brought up to date, and all the members of the Party were exercised daily in plan drawing, and had some instructions in the use of the plane-table.

VI.—Extract from the Narrative Report, dated 30th August 1877, of Major A. Pullan, S.C., Officiating Deputy Superintendent, 3rd Grade, in charge of the Kattywar Party.

Out-turn of Work.

The out-turn of work for season 1876-77 was an area of 1,716 square miles topographically surveyed, and 2,062 square miles of triangulation prepared in advance, while 752 linear miles of traverse were executed in order to demarcate the boundaries of the various States, and to check the plane-table survey of the country.

Expenditure.

The total expenditure for the survey during the past financial year was Rs. 70,082, and the out-turn of work finally completed was 1,716 square miles. Thus, deducting Rs. 3,600 cost of boundary survey establishment, we shew an average expenditure for finished work of Rs. 38-7 per square mile.

A portion of the country under survey was very wooded and hilly, and covered with intricate ravines, and the Surveyors could progress but slowly; added to this, I was deprived of the services of Messrs J. Peyton and W. Oldham, both good plane-table, Surveyors, who were transferred to other surveys, and had to replace them by Mr. Keating who, though a promising young Surveyor, had to be taught plane-tabling *ab initio*. One of my best native plane-tablers, Nilkant Vital, was also laid up before he had completed one plane-table, and taking his discharge from the Department proceeded to Poona. Mr. Gwynne, my best plane-tabler, was employed at my head-quarters from 4th December to 25th January, drawing the fair map of Sheet 38, which I had not been able to do more than commence in recess quarters at Poona; thus the smaller out-turn of work, as compared with season 1875-76, is, I think, fairly accounted for, and the amount executed this season will not be considered as insufficient.

Departure for the field.

The Party started for the field on the 25th October, the heavy baggage and horses with the subordinate native establishment proceeded, as in former years, to Gogo by "Patimar" boats, and arrived there on the 5th November after a rather rough passage. By the 15th of this month the various Surveyors were on their road to their work, I myself proceeding, *viâ* Jetpur, to Patanwao, at the foot of

the Osham hill, while Mr. Gwynne proceeded with the main camp to Upleta and set to work at the drawing of fair Sheet 38, while he also employed his mornings in instructing Mr. Keating in the use of the plane-table.

Major N. Pullan.

I commenced the survey of Osham hill on the 5th December, and was employed on that and the survey of the Bhadar river, and in the instruction and daily supervision of two new plane-tablers, Mr. Keating and Narsu Dinkar, until the 24th December. The remainder of the field season I was employed in examining the plane-table Surveyors, besides making a twelve days' march about the Gir forest to examine the nature of the ground on which Mr. Bell was employed, and the character of his triangulation. On the 10th of April I reached Virawal, where I remained employed in the comparison of plane-table borders and miscellaneous office work until the last plane-table had been examined by me. I then started for Bombay *en route* to my recess quarters at Poona, which station I reached on the 14th May.

J. McGill, Esq., Assistant Superintendent.

Mr. McGill executed the triangulation of Sheets 54, 55 and 56 in his usual good style, and completing his work on the 15th March he proceeded to Virawal, where he occupied himself in bringing up angle books, preparing abstract of angles, and arranging triangle sheets for computation until the 11th April, when he left for Poona to assume charge of the Tidal and Leveling Party during the absence of Captain A. W. Baird, R.E. He was accompanied by Mr. Fielding and Head Sub-surveyor V. R. Gadboli, together with a small office establishment. On arrival at Poona, Mr. McGill opened office, and, in addition to his own special work, he superintended the preparation and projection of fair Sheet 50 of Kattywar. Mr. McGill's capacity for work and his untiring industry are well known, and it is only necessary for me to say that he worked this year as he has always done.

Mr. F. Bell, Surveyor, 3rd grade.

Mr. F. Bell was entrusted by me with the triangulation of Sheets 39 and 49; the area triangulated by him was 952 square miles, a portion of the ground being very thickly wooded and sparsely inhabited. As far as I can judge at present from the computations, the work seems of good quality, and Mr. Bell may be fairly said to have done a creditable season's work.

Mr. N. C. Gwynne, Surveyor, 3rd grade.

Mr. Gwynne was employed at my main camp from the 4th December to 25th January in drawing fair map of Sheet 38 of Kattywar. At the end of January he proceeded to take up a plane-table in the Alech hills, a very laborious and difficult piece of work, which he executed most skilfully, and which I found on examination to be most accurate in detail. Mr. Gwynne's out-turn of field work was 129 square miles. Mr. Gwynne worked, as he always does, hard and well.

Mr. W. A. Fielding, Assistant Surveyor, 2nd grade.

Mr. Fielding executed 173 square miles of topography in a very artistic and at the same time careful manner. I can only endorse again the favorable report I have always had the pleasure of making on Mr. Fielding.

Mr. G. Hall, Assistant Surveyor, 3rd grade.

Mr. Hall's out-turn of work was 204 square miles of topography, well surveyed and neatly drawn. Mr. Hall steadily improves, and is a very useful and willing assistant.

Mr. H. Corkery, Assistant Surveyor, 4th grade.

Mr. Corkery shews a good out-turn of 246 square miles correctly and neatly done. I regret that, under existing circumstances, it is useless to bring forward Mr. Corkery's strong claims for promotion to the next grade.

Mr. J. Keating, Assistant Surveyor, 4th grade.

Mr. Keating joined me in October, and after learning the use of a plane-table, he executed, under careful supervision, 149 square miles of correct and neatly-drawn work. Mr. Keating promises to make a good plane-table Surveyor, and his season's work is highly creditable to him.

Mr. V. R. Gadboli, Head Sub-surveyor.

Mr. Gadboli was employed at my main camp during the major part of the season in projecting points on plane-tables, and various miscellaneous duties. He executed 50 square miles of plane-tabling correctly, but his drawing was feeble and wanting in expression. Mr. Gadboli is more in his element in an office than when employed on out-door work.

The remaining 5 plane-table Surveyors all did good work, more especially Narsu Dinkar, who used a plane-table for the first time very successfully.

General health.

The season under review was a very healthy one, one or two cases of fever being all the sickness the party was troubled with. There was, I believe, a slight outbreak of cholera at some of the towns on the seaboard near Virawal; but, as far as the Survey was concerned, the general health was excellent.

Natural features.

To the south-west of Sheet 46 lies an intricate net-work of low ranges known as the *Alech* hills. They cover an area of 60 square miles, and are very sparsely inhabited. The few villages that there are, are placed in strong positions, and are surmounted by police towers, reminders of the wild times when the village watchmen, matchlock in hand, scanned hillside and valley with anxious eye, ready to mark an enemy's approach and give a timely alarm. Panthers abound in the narrow gorges

of this range, but they are gradually becoming thinned as cultivation and civilization advance. In a narrow valley not far from Dhánk, and on one of the eastern spurs of these hills, are some very curious caves, now closed by order of the Superintendent of the Gondal State. Mr. Fielding endeavoured to enter and explore them, but found them thoroughly blocked up. These caves were a few years ago a private resort of the bands of wandering "Bharwattias" or outlaws, who infested the hilly country of Kattywar. These ruffians are even now occasionally troublesome in this part of the country, as, not further back than January last, a body of them attacked the small village of Virdi, in the Aleeh hills, and killed and wounded several of the people. Another peculiar feature in the country under review is the isolated basalt hill of *Oxhan*, which rises abruptly from the plain to an altitude of 1,032 feet above the sea. The hill is surmounted by a fort, once a very strong place, the ruined walls of which stretch round the hill, testifying to the strength of the defences in days gone by. Two good springs of water exist on the hill, one near a temple called Matri-ki-Devi being especially pleasant to the taste. Large blocks of obsidian, singularly like coal, are scattered about and crop up along the basalt and trap, and there are many external evidences that the hill is decidedly volcanic.

Towns of importance.

The principal towns which came within the area of country surveyed this season are—

In Sheet 46—

Bháyawadar—Population 5,563; under the jurisdiction of the Gondal State. The town is situated in a fertile, well-cultivated country, the population being chiefly Mussulmans, who do a thriving trade in cotton.

Jodhpur—Population 4,004; a town under the Jam of Nawanagar; of some importance.

Dhánk—Population 2,894; a town under the Gondal Durbar, formerly much more populous than now, and showing all the signs of a once important place now falling into decay.

In Sheet 47—

Uneta—Population 6,500; one of the largest towns under the Gondal Durbar, the people Mussulmans, Kunbis and Kolis, the trade of the place being in cotton.

Dhoraji—Population 15,562; under the Gondal Durbar; a very large cotton emporium. The Superintendent of Police, Gondal State, resides here; and there are also large cotton mills under European superintendence. Dhoraji is next to Jamnagar and Junagarh, the most populous town in Kattywar.

Kuntiyána—A town on the Bhadar river, and belonging to the Nawab of Junagarh; is a considerable place with a population of 9,912. The surrounding country is very well cultivated, cotton as usual preponderating.

Bántwa—With a population of 8,832; is a large place, the residence of a Babi Sahib, a connection of the Nawab of Junagarh. The little State of Bantwa is shared between three brothers, among whom the Bantwa Chief takes precedence.

Wanthali—With a population of 6,056; is a handsome town on the Uben River. It is surrounded by some of the most highly-cultivated ground in Kattywar. The town belongs to the Junagarh Nawab.

In Sheet 50—

Pátan—A fine, old, walled town on the southern seaboard of Kattywar, with a population of 6,856; is remarkable for its ancient and world-known Hindu Temple of Somnath. The temple is now a venerable ruin fast falling to pieces, and it would be creditable to the Junagarh Durbar if some steps were taken to arrest the progress of its decay. The sand is fast silting up round the black time-stained walls of the old city; in some places but a few feet of masonry are seen struggling out of the ever-increasing sand heaps. A sand-bar blocks the shallow mouth of the Harna river, and I never saw a place more thoroughly "a memory of the past" than Pátan.

Virawal—Five miles west of Pátan, with a population of 10,735, promises to be a place of importance. There is a good light-house on the pier, and if the Durbar carry out to completion their long-planned, but slowly-executed, break-water, the port of Virawal will afford a welcome shelter to the various crafts which ply along this rocky and dangerous coast.

These two towns are closely connected one with the other, and are commonly spoken of as *Virawal-Pátan*.

Rivers.

The rivers which are noticeable in this season's work are the *Moz*, the *Bhadar*, the *Ojat*, the *Uben*, and the *Harna*. The Moz and the Bhadar, the most considerable streams in Kattywar, have been already noticed in former reports. The Ojat, a deep stream with a considerable amount of water in many places, is joined by the Uben near Wanthali, and, after pursuing a tortuous course to the west, falls into the Bhadar river close to its mouth at Navi Bandar, on the shore of the Gulf of Cutch.

The Harna takes its rise in the heart of the forest-clad hills of the Gir, its rocky picturesque banks, covered with a dense growth of "Karanda" bush and "Jawbal," are the favorite haunts of the lion and the panther, and the beautiful stream after winding its way through a wild wooded country emerges for a few miles into the plain near Patan, and falls into the sea about a mile south of that ancient town.

TABULAR STATEMENT OF WORK EXECUTED BY THE KATTYWAR PARTY, GREAT TRIGONOMETRICAL SURVEY, DURING THE FIELD SEASON 1876-77.

Details of Triangulation.

Observer's Name.	Instrument.	Area triangulated in square miles.	Three Angles observed.						Two Angles observed.				Average No. of trigonometrical points per square mile.	Average No. of heights per square mile.	Pillars built.	Elements computed.	Remarks.
			No. of stations fixed.	No. of stations visited.	No. of triangles.	Triangular error.	Error per mile.	No. of heights.	No. of heights of old stations.	No. of intersected points.	No. of triangles.	Error per mile.	No. of heights.				
							Ft.					Ft.					
Mr. J. McGill ...	Cooke and Sons' 7" ...	1,110	37	53	79	9″0	0·4	49	10	500	881	1·1	280	0·5	0·8	270	537	
„ F. Bell ...	Troughton and Simms' 6"	952	46	57	81	9·0	0·5	44	6	391	673	0·9	109	0·5	0·2		432	

Details of Topography.

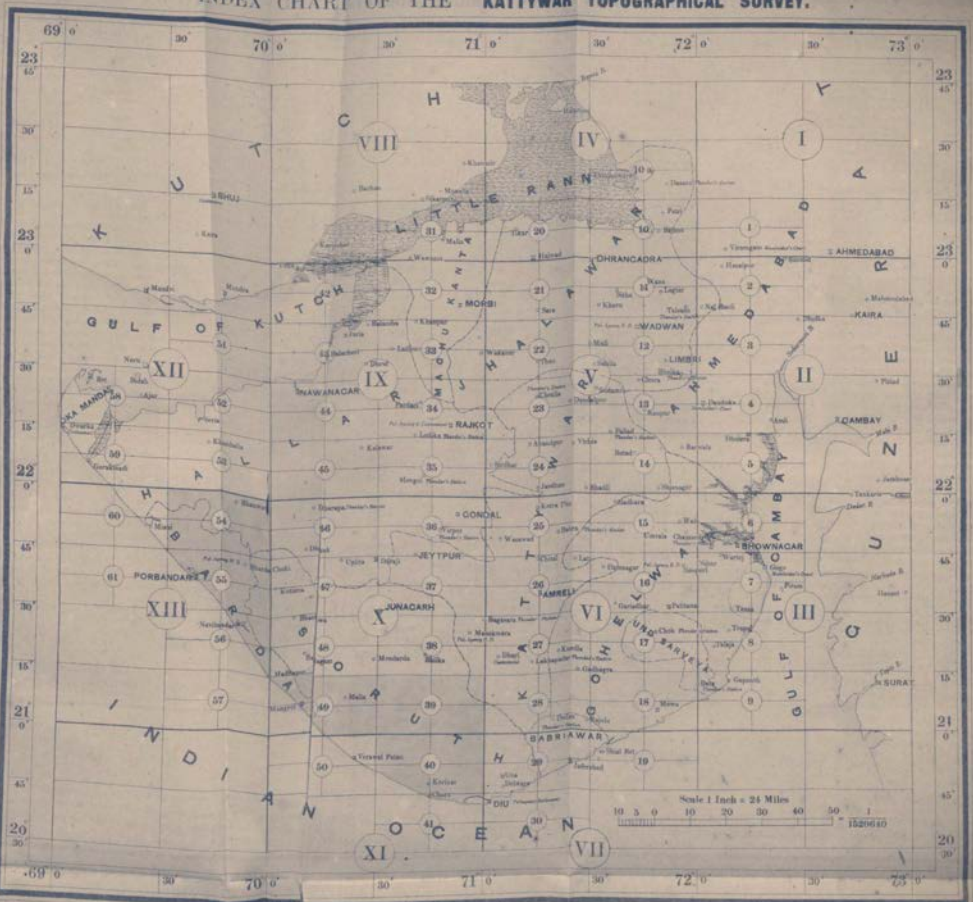
Name.	Area surveyed in square miles	No. of plane-table stations per square mile.	Remarks.
Major A. Pullan, S.C.	7	9·7	Employed in drawing fair copy of Sheet 38.
Mr. N. C. Gwynne	129	6·6	
„ W. A. Fielding	173	10·4	
„ G. T. Hall	204	9·2	
„ H. Corkery	246	9·4	
„ J. Keating	149	11·4	
Sub-Surveyors.			
Wissaji Raghunath	50	11·6	Also employed in office work at head-quarters' camp.
Narsu Dinkar	86	10·0	
Krishnaji Govind	122	13·4	
Keshu Vital	174	11·4	
Ganesh Ramchandra	209	11·7	
Vishnu Balwant	154	9·4	
Nilkant Vital	13	23·0	
	1,716	11·3	

Details of Traversing.

Name.	Instrument.	Linear miles of traversing.	No of stations.	Average error per 1,000 links.	Average angular error per station.	Lats. and departures.	Remarks.
					″		
Narsu Dinkar	5 Inch	85	234	0·9	5·5	2,131	
Krishnaji Govind	Ditto	36	108	1·4	14·9		
B holajBhoskar	Ditto	225	531	0·6	7·9		
Tukaram Chowdri	Ditto	406	1,258	0·7	13·1		
		752	2,131	0·9	10·3		

GREAT TRIGONOMETRICAL SURVEY OF INDIA

INDEX CHART OF THE **KATTYWAR TOPOGRAPHICAL SURVEY.**



The numerals 1, 2, 3 &c., indicate the sheets on the scale of one inch to the mile. The one inch sheets are divided into 8 sections known as the N.E., N.W., S.E., & S.W., sections of sheet, of which a few copies will be published on the scale of the original Survey, viz., 4 inches to the mile, for the use of land officials.

The numerals I, II, III &c., indicate the degree sheets on the Scale of 1 inch to the mile.

Dotted country Topographically Surveyed up to 1875-76.
" " " " in 1876-77.
" " Triangulated in advance
" " Triangulated and traversed in advance

Photolithographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Dun, October 1877.

VII.—Extract from the Narrative Report, dated 7th September 1877, of Lieutenant J. E. Gibbs, R. E., Officiating Assistant Superintendent, 2nd grade, in charge of the Guzerat Party.

Lieut. Col. C. T. Haig, R. E., in charge (until 16th March).
Lieut. J. E. Gibbs, R. E., (in charge from 17th March until 14th June inclusive).

Mr. A. D'Souza.
„ A. D. L. Christie.
„ C. H. McA Fee.†
„ J. Hickie.
„ G. D. Cusson.
„ S. F. Norman.
„ C. A. Norman.

Sub-Surveyors.

Mr. H. G. Ferns.*
„ A. George.*
Gopál Vishnu.
Bálkrishna Bábáji.*
Lakshuman Ghorpure.*
Ganesh Náráyen.*
Ráoji Náráyen.*
Bhau Govind.
Gannesh Bápuji, 2nd.
Balwant Govind.
Ganesh Bápuji, 1st.†
Mukund Dinkar.†
Govind Gopál.†
Monaji Abu.*
Balwant Rájárám.
Sáyana Saibu.
J. V. DeSouza.*
Virapa Piraji.
Rámchandar Vishnu.

Leveling Party.

Dámodhar Rámchandar.
Sitárám Yeshwant.

Revenue Survey.

Sivaji Nánáji.
Kubar Parbhudás.
Jugal Mánsukhrám.
Parbhu Kisor.

2. The personnel of the Party has been as shown in the margin, and from among them those marked* were employed throughout the field season in the permanent drawing office of the Party, while those marked† were employed partly in field work and partly in the drawing office.

4. Taking Sheet 15 first into consideration, we find in it two towns enjoying municipal self-government.

Sheet 15.

5. The more important one is the city of Surat, in Lat. 21° 11′ N., and Long. 72° 52′ E., having an aggregate population of 107,149 according to the census of 1872. Probably the earliest notice of the place is the mention of its invasion by Persians in A. D. 560. Muhammad Toglak Shah, Emperor of Delhi, sacked the city in 1350, and in 1512 it was discovered and sacked by the Portuguese. The castle was erected about 1542 by Sultán Muhammad Shah, King of Guzerat, as a protection against pirates and faranghis. In 1573, after a brave defence, the city was surrendered to Akbar, the great Moghal Emperor. After this Surat became the chief seaport of the Empire, the storehouse of the riches of India, and the rendezvous of traders from all nations. The first English ship to arrive at Surat was the *Hector*, Captain Hawkins, in August 1608, bearing letters from the Company and from King James I to the Great Moghal, Jahángir, requesting the intercourse of trade. In spite of obstructiveness on the part of the jealous Portuguese, a treaty was drawn up on the 21st October 1612 between Captain. Best and Shaikh Safi, Governor of Ahmedabad, which authorized the establishment of an English factory, and the appointment of an Ambassador at the Moghal Court. This treaty was finally confirmed by an Imperial farmán dated 25th January 1613. The Portuguese struggled long to suppress the English trade, but were worsted in all the important engagements. In 1618 the Dutch obtained a farmán for establishing a factory. The French and Swedes also started factories, but the history of their trade is not brilliant. In 1650 the English factors were imprisoned and had to pay heavily for their release. In 1656 the rival companies in England coalesced, and in 1658 all their factories in India and in Persia were placed under the control of the President and Council of Surat. In 1662 Sir George Oxenden became President, and under him in 1670 the Company's servants gallantly saved the factory and castle from the attack of Sivaji, the great Mahratta Chief, who captured and plundered the city; he had plundered the native town once before in 1664. The defence of the castle was the first engagement between European and Indian troops. In consequence of their generous defence of the property of others, Aurangzeb gave the English further privileges. In 1685 Sir John Child, the President, was ordered to remove his seat to Bombay, where he was soon after appointed Governor General over all the Company's settlements east of the Cape of Good Hope. The English factory now passed through many vicissitudes of fortune, but, on the whole, prospered. In 1748 Moyan-ud-din seized the castle and assumed the title of Nawáb of Surat. On the 4th of March 1759 the English took the castle from the Nawáb, and a dual Government ensued during the reigns of 3 Nawábs, these conducting the civil administration, while the English held the military and naval commands. This arrangement proving very bad, the Company obtained, by treaty on the 15th May 1800, from the Nawáb Nazar-ud-din, whom Mr. Duncan, the Governor of Bombay, had just placed on the "gadi," the entire government of the city and dependencies of Surat. In 1802, by the treaty of Bassein, the Peshwa surrendered his interests in the city and zillah, and by the treaty of Sirji Anjangaon, Sindia surrendered all his claims. In 1842 the last of the direct line of Nawábs of the creation of 1800 died.

Surat.

Surat lies on the left bank of the Tapti, about 13 miles from its mouth, and on the chord of a long bend. The outer wall of the city is about 5½ miles long, and an irregular semicircle in shape, with 12 gates, and some 40 tower-bastions at unequal intervals. There used to be an inner wall about 2¼ miles long. The castle consits of 4 massive round masonry towers, connected by curtains, and a ravelin that was added by the English on the river face. The soil being a treacherous clay of great depth, all buildings suffer, the walls cracking and losing their perpendicularity, and the modern public buildings show that art has not succeeded in overcoming the natural difficulty.

The principal objects of interest are the English and Dutch burial-grounds outside the walls to the north. The old factors seem to have vied with each other in having magnificent tombs erected over their remains; but now many have fallen, and many are almost past repair.

Surat is the chief town of a Collectorate, and possesses a civil and a military station; the latter contains now only one Native Infantry regiment, whereas years ago there were a large

force of troops and a naval commodore stationed at Surat. The city has been subjected to several catastrophes. In 1810, 1822, 1835 and 1837 there were great floods causing widespread destruction, and in the last three named years there were also extensive fires. Fires of smaller extent have been frequent. To obviate disasters from floods, Captain Fulljames in 1838 designed and carried out a cut along the chord of the great curve in the river, and, passing to the south of the city, this succeeded for a time in drawing off the superfluous water, but later floods have proved too much for it. Newer municipal works have been more successful in preventing the inundation of the city. The chief want in Surat is good water; almost all the wells are brackish, and among them are many that some years ago were sweet. A large project is in hand which, if carried out, will bring a plentiful supply of pure water for drinking and irrigation from above some rapids near Kamlápur about 35 miles above Surat. The Tapti has shoaled very much since when merchantmen of 500 to 600 tons anchored under the walls of the castle, and the navigation of the river was simple. Now there are a bar and many mud banks off the mouth of the river, and the maritime trade of the city has departed, fishing boats and ferries alone being left.

The present industries at Surat are cotton-ginning and spinning; the manufacture of cotton *saris*; silk weaving and embroidery with china silk; brocade or "kinkháb," paper-making, lacquered work, "Bombay" inlaid box-work, and distilling spirituous liquor from the sap of the Palmyra and date palms.

Ránder.

6. The other municipal town in Sheet 15 is Ránder, on the right bank of the Tapti, and connected with Surat by the new "Hope" bridge. Its population was 10,280 in 1872. It is one of the oldest cities in southern Guzerat, and after A. D. 1223 became a stronghold of Arab merchants called Náyatás, who expelled the Jáin rulers of the town. It was once the home of many fishermen; now it is of rising importance, containing mills for ginning and spinning cotton, and is the home of a great number of Bohoras and other native merchants.

Dumas.

7. At Dumas on the coast, between the estuaries of the Tapti and the Mindhála, is a small collection of bungalows forming a seaside retreat for the European inhabitants of Surat.

Sachin.

8. Into Sheet 15 comes part of the Sachin State. This estate of seventeen villages was secured to Sidi Abdul Karim, better known as Bálu Mia, by a treaty between the Peshwa and Sir Charles Malet, then Resident at Poona, on the 6th June 1791. Bálu Mia agreed to abide by the terms, which were that he should resign all his hereditary claims to the territory, forts and dependencies of Janjira, and instead receive the Sachin estate, and abstain from hostile acts against either the Peshwa or the British Government. He afterwards obtained the title of Nawáb of Sachin from the Emperor of Delhi. The Nawábs are by descent Habshis, or Abyssinians. In 1835 all the estate, except two villages, was taken under the management of the British, at the request of the Nawáb, with a view to the liquidation of his debts. The administration of justice is in the hands of the British Government, and the present Nawáb being a minor, the Collector of Surat, as Political Agent, is in charge of the whole estate.

Sheet 15.

9. The Tapti, or, as it should be, Tápi, river forms the southern boundary of the great cotton-growing districts of Guzerat. It is spanned by a fine girder bridge of the B. B. and C. I. Railway at Amroli, and again by the "Hope" girder bridge at Surat. In Sheet 15 are also the estuary and part of the Mindhála river. The country is very flat, and has many arms of salt land, called "khári," overflowed at high spring tides, running in from the rivers between the cultivated areas. The latter bear large clumps of the Palmyra palm (*Borassus flabelliformis*) and the wild date palm (*Phœnix sylvestris*,) which yield enormous quantities of Tári liquor.

Sheets 28, 29 and 30.

10. In the northern portion under survey this year stand the city of Baroda, the town of Dabhoi, and others of minor importance.

Baroda.

11. The city of Baroda, in Latitude 22° 18' N., and Longitude 73° 15' E., is the capital of the territories of the Gáekwár, and lies on the left bank of the Vishwamintri river, a tributary of the Dhádhar.

Baroda, once an ancient stronghold of the Jáinas, was subsequently wrested from them by the Muslim Tartar dynasty of Hindusthán. It was called Chandanavati (city of sandalwood) by Chandan, a Rájput King, one of its conquerors. Afterwards it was named Varavati (abode of warriors.) Priestly influence changed this to Barpatta (leaf of the bar). Hence Baroda, or as the natives write Barodra. The Muhammadan name for the city used to be Daulatábád.

Baroda has belonged to the family of the Gáekwárs since 1732, when it was taken from Abhi Singh, the Mussulmán governor of Guzerat, by Máhádáji Gáekwár, after the murder at Dákor of his brother Pilaji, the "Sena-Kháss-Kháil," second in command under Dhabáre, the Peshwa's Senápati. Damáji, the eldest surviving son of Pilaji, then came forward, and before long became the most powerful Chief in Guzerat, but having plotted in concert with Tára Bái, Báláji Báji Rao (the Peshwa) treacherously enticed him to his camp and made him prisoner, and only released him in 1753 on the following terms:—equal partition of districts then held by the Gáekwár, and of all future conquests; 15 lakhs indemnity for past contributions due; military assistance when necessary; an annual tribute of 5½ lakhs; and certain other minor conditions. From this time dates the Peshwa's permanent supremacy in Guzerat.

During the latter part of the 18th century it was the policy of the British to support the Baroda Government as a counterpoise to the Peshwa. On the 26th January 1780 a treaty of offensive and defensive alliance was signed by Faté Singh Gáekwár and General Goddard, on terms approved by the Supreme Government. At the beginning of this century the finances of the Baroda Government were in an almost hopeless state of confusion and embarrassment, and Major Alexander Walker, who had been appointed Resident, made strenuous efforts to remedy the evil. In 1802 orders were given for the reduction of the military force in Baroda; but the Arab mercenaries revolted, confined Anand Rao Gáekwár, and released Kanháji, the rival claimant of the throne. Serious disturbances in Guzerat being expected, Major Walker called for a European regiment from Bombay in aid of the local subsidiary force, and Colonel Woodington invested the city of Baroda, which was surrendered after an energetic defence for ten days, and the Arabs, after receiving all that was due to them, were forced to quit the country. In return for the assistance from the British, a new treaty was concluded on the 21st April 1805, consolidating previous stipulations and adding others, among which were the increase of the subsidiary force from 2,000 men to 3,000, besides a company of artillery; and the cession of certain districts to the British as well as the Gáekwár's share of the "chauth" of Surat.

The murder at Pandharpur on the 14th July 1815 of Gangádhar Shástri, the agent of the Gáekwár, by Trimbakji, the unscrupulous minister of Báji Rao (the Peshwa), was one of the first of a series of vicious and intriguing acts that led to the dissolution of the kingdom and dynasty of Báji Rao. In November 1817 a treaty was concluded, in which, among other conditions, the Peshwa renounced all rights north of the Narbada, and relinquished all future demands on the Gáekwár. In return for the benefits thus obtained for them by the British Government, the Baroda Darbár assigned more territory to the British as payment for an augmentation of the subsidiary force in Guzerat.

In 1820 the Gáekwár agreed for the future to refrain from interfering with his tributary Chiefs in Guzerat, except through the medium of the British Government.

The subsequent history is of too recent date to be given in a report of this kind. I need only mention that Baroda has been brought prominently into notice lately by the Commission that sat in 1875 to enquire into the attempted murder of Colonel Phayre, the Political Resident, and in consequence of the investigations of which, Malhar Rao Gáekwár was deposed and sent in arrest to Madras.

The present Gáekwár, Sáyaji Rao, being a minor, the administration of the State lies in the hands of the Diwán, Sir T. Mádhava Rao.

Baroda contains a citadel, about 970 by 820 yards, surrounded by a wall having four gates and some 50 bastions, and divided into four square sections by two cross streets. To the south and east are other divisions of the city, which are surrounded by a similar bastioned wall. In the western portion of the city is the old Kothi or Residency. The enclosure, which is surrounded by a wall, is the site of the Jail and the new public offices. The Gáekwár's usual residence is the Moti Bág, and the Diwan's the Mastu Bág, in the suburbs to the S. W. of the town. The old palace is close to the north of the clock tower in the centre of the citadel, and is now used for public offices. Malhar Rao Gáekwár built close to this a magnificent palace, the Nazar Bág, which is of a pure white color, and much ornamented with carvings. In the interior, which is used for Darbárs, there are frescoes executed by a European artist. Malhar Rao had the tower built to such a height as to exceed that of the palace at Makarpura, built by Khande Rao Gáekwár. About ½rd of a mile north of the Moti Bág palace is a celebrated well called the Náu Lákhi Báori, and just to the west of the palace is the Máhárája's school, a fine new building, where the young Gáekwár studies, in company with sons of the nobility of the State, under his tutor, Mr. Elliot of the Bombay Civil Service.

There are some fine tanks at Baroda, especially the Sur Ságar in the centre of the town. There is a Hindu bridge over the Vishwamintri, and across a small tributary just beyond there are two bridges, one that was built by Colonel Waddington of the Bombay Engineers, of very elegant design, and the second of native construction, built because the Gáekwár was afraid to cross the other on an elephant, for fear lest the thin-looking crown of the arch should give way. Below the bridge over the Vishwamintri is a bund, which keeps in a large supply of water throughout the hot weather. There is a capital road leading from the city to the cantonment and Residency. This road is raised on an embankment, and yet communication is sometimes interrupted by floods. The Residency is a fine, though very old, house, and stands in large grounds. Opposite is the Rewa Kánta Political Agent's house and office, standing in a capital garden. The cantonment now contains a half battery of artillery, a squadron of cavalry, a detachment of a European and two Native Infantry regiments. The bungalows of the officers are in two rows separated by a broad strip of turf, along which the fine isolated hill of Páwágarh may be seen in the distance. In a central position stands a column erected to the memory of Mr. Williams, once Resident at Baroda, but it bears no inscription. There is an English church that was consecrated by Bishop Heber, a Roman Catholic chapel, and a public garden.

Dabhoi.

12. Dabhoi, situated in Latitude 22° 8' N., and Longitude 73° 28' E., is an ancient fortress, the walls of which form an irregular four-sided figure, approaching to a square. The N., E., S. and W. walls are respectively 1,025, 900, 1,100, and 1,025 yards long, and have a round tower at each angle. The remains of its fortifications, double gates and temples indicate great magnificence. The stones

used are chiefly huge blocks of a very durable sandstone. Of the gates, by far the finest is the Eastern or Hira Gate (Gate of Diamonds). It is covered with handsome carvings representing groups of warriors, animals, birds and serpents. There is a quaint legend about a man having been built up alive in the masonry at the King's orders; but his protectress, the Ráni, used to have him fed by a large quantity of ghi being poured down an opening, which is shown to this day.

Within the walls is a large tank, lined with hewn stone, and having steps all around.

The legend about the building of the city is interesting, and may be found in Forbes' "Oriental Memoirs," Vol. II. It is said to have been built by Siddharaja Jayasinha in about A. D. 1100.

Dabhoi was for a long time inhabited by Hindus only, no Mussulmán being permitted to reside within the walls, or to wash in the tank. A young Muhammadan named Sayad Bála, on a pilgrimage with his mother Máma Dukhri, in ignorance of the prohibition, ventured to bathe in the tank, and the Brahmans prevailed on the Rája to mutilate him, and he died. Máma Dukhri at once returned home and sued to her sovereign for redress. He sent a large army under his Vizier, which took Dabhoi after a long siege. The Vizier had all the fortifications destroyed except the western face and the four double gates. When Máma Dukhri died she was revered as a saint, and was buried in a grove near the Hira Gate; by her tomb is a stone of ordeal, and the proof of innocence lies in being able to wriggle through the perforation in the stone.

After this Dabhoi was for many years almost deserted. When the Mussulmáns finally conquered Guzerat, Dabhoi became more populous, and was held by them for two centuries. The Mahrattas then obtained possession of it, and partly rebuilt the walls. During the campaign of 1775 it submitted to Raghoba Peshwa, who levied a contribution of three lákhs, which the inhabitants were scarcely able to pay. In January 1780, General Goddard took the town, on his way to attack Fate Singh Gáekwár, who however gave in and concluded a treaty with the English (see para. II). Mr. James Forbes, auther of "Oriental Memoirs," was left as Collector of Dabhoi till the 24th April 1783, when the pargana of Dabhoi was with others handed back to the Mahrattas according to treaty.

Dabhoi is now the chief town of one of the Talukas of Baroda territory, and has within the last three years gained in importance by the State Railway joining it with Miágám station of the Bombay, Baroda and Central India line. It is proposed to connect it also either by tram or railway with Baroda.

Rewá Kánta.

16. In Sheets 28 and 29 are several small estates, under the Pándu Mewás, Rewá Kánta, the most important, being those belonging to the Thákurs of Bhádarwa, Sihora and Cháliar.

Udhad Tenure.

17. In the portion of Kaira under survey are several villages held under a tenure that has not yet been described in these reports, *viz.* Udhad (a Guzerati word signifying "in a lump"). The origin of this tenure dates back as far as the days of Akbar, and it then meant that a village having been carefully measured and an average struck of the value of the produce the land would bear, one-third of this amount was taken as a fixed rental, to be paid without reference to the extent or nature of cultivation, and without any right on the part of the Government to interfere in the internal management, and the whole village community was made jointly responsible for the payment. The oppression exercised subsequently by the Mahrattas partially broke down this system, which received modifications, leading to the present sub-division of "Narwa" and "Bhágwár" tenures.

In "Narwadári" villages (almost confined to Kaira) the lands have never been assessed at rates per beegah; the assessment was fixed in a lump by the Collector, and has in most villages remained unaltered for many years.

In "Bhágwári" villages the lands were assessed at rates per beegah, at the same time as other villages of the district, and their total beegotee assessment forms the lump assessment of the village.

Description of Sheets 28, 29 and 30.

18. With the exception of some patches of open country in the eastern half of Sheet 29, a strip of open country extending along the southern portion of Sheet 28 from near the Mai river, to almost as far as Hálol in the Panch Máhals, and the southern portion of Sheet 30, the country in those Sheets is thickly wooded. In some parts the forest is very dense, the mango being by far the commonest tree, but mixed with the tamarined (especially near village sites), the *mahura* (Bassia latifolia), *kiení* or *rayan* (Mimusop indica), *kawat* (Feronia elephantum, *pilwa* (Salvadora persica), *pipal* (Ficus religiosa), *bar* or *wad* (Ficus indica,) *nim* or *lim* (Mela azadirachta,) and others less common.

The country is also very hedge-bound in parts, especially to the west and south of Baroda, the hedge containing cactus, milk-bush, *arni* (Clerodendron phlomoides) *sitáphal* (Anona squamosa), *jetimad* (Cadaba indica), kari (Capparis aphylla), and other shrubs of the caper tribe. Close to Baroda there are some hedges of aloes, very difficult to cut through. The suburbs of Baroda are celebrated for the magnificent specimens of tamarind and nim trees to be found there. Here, too, may be seen some very large baobabs, *gorak-amli* (Adansonia digitata), which has been planted at all the ancient seats of Mussulmán power. On approaching Hálol and Kálol in the Panch Máhals many brab, or palmyra palms, are met with.

There are few undulations of surface, except some low hills in sheet 28, and along the banks of the Mahi river. The streams have cut deeply into the soft soil.

The Mewási Rewá Kánta States (Mewás, a fastness) consist of very wild and intricate country, full of deep nalas and jungle-covered ravines, affording great facilities to robbers or outlaws.

The soils are chiefly as follows:—to the right of the Mahi river $\frac{9}{10}$ths is of a light and sandy nature, and the rest approaching to a black loam. South of the Mahi are yellowish sands, loams and clays, till south of Baroda there is blackish loam, very good for rice, containing a large quantity of white sand; then about 6 miles to the south is a slight rise in the country, after which comes black cotton soil varied by loams. In the small portion of the Panch Máhals under survey the soil was chiefly a dark loam.

Rivers.

19. The principal river in the northern area under survey is the Mahi, which traverses Sheets 28 and 29, and forms the eastern boundary of the Kaira Collectorate; the banks of this river are reticulated by deep ravines, especially at the junctions with the Mahi and its tributaries, the Mesri, the Karad and the Mini rivers. The Mahi has cut its way down deeply into the alluvial strata, its steep banks being in places over 100 feet high. The banks contain beds of kankar, which is burnt for lime. The bed is clayey or sandy in most parts, but in the upper half of Sheet 28 the trap crops out all along the bed. In Sheet 30 is the Dhádhar river, with its tributaries the Vishwamintri (on which is situated Baroda) and the Deo; the Vishwamintri again in Sheet 29 has a tributary the Mota Suria. There is also a small tributary of the Dhádhar, *viz.*, the Rangai, which again has a tributary, the Rás; the latter is a peculiar feature, as although at its junction with the Rangai it is only a streamlet with banks about 10 feet deep, it is almost of the same size where it enters Sheet 30, 16 miles to the east, and its course is lined with trees in an otherwise fairly open tract of country.

Lieutenant Gibbs.

22. I was at first employed in triangulating and traversing Sheets 26 and 27 with the assistance of four native Sub-surveyors. I made a network of triangles based on the principal stations Ghorarao H. S., Jheria H. S. and Wardhári H. S., extending it until the country became too densely wooded to admit of triangulation without very expensive ray-cutting, but I have succeeded in securing several bases for continuation along the margins of my sheets. I also executed five main traverses. I worked with one of Elliott's 7-inch omnimeters, to test it, but found it to be a very inferior theodolite, the graduations being inaccurate and coarsely done, so that in order to ensure good results I had to repeat oftener than would have been necessary with an ordinarily good instrument.

While triangulating I collected rock-specimens for the purpose of determining the petrology of the district, which is very interesting in the variety of rocks present, and in the thin layer of Deccan trap that reaches Sheet 26; but the results, together with my notes on the botany of the district, can be improved by further observation by the topographers next field season, so that it is best to reserve them for next year's report.

I rejoined head-quarters on the 2nd March, and remained with Colonel Haig till he gave over charge at Surat. Having then re-visited the drawing office at Baroda, I started on a tour of inspection of plane-tables, visiting each of the topographers in succession.

Mr. D'Souza.

23. Mr. D'Souza had charge of the topography of Sheet 15, where he executed the greater part of the northern portion, and besides examined the work in the rest of the sheet. Under him was Bhau Govind, who turned out over 200 square miles of topography in very good style.

Mr. Christie.

24. Mr. Christie was employed first in the preparation of Sheets 6 and 7. As there were a principal series running down the eastern half of the sheets, another along the southern margin of Sheet 7, and a minor series along the western edge of both sheets, Mr. Christie had only to observe 2 triangles, and the rest of the work was all done by main and branch traverses based on the trigonometrical stations. This method was very advantageous; as for triangulation so much ray-cutting would have been necessary that the work would not have been finished in the season.

Mr. Christie was called away on the 14th of February to go to the Dángs. There he executed some minor triangulation and 3 omnimeter traverses in the river beds, working at first with Mr. C. Norman till the latter was thoroughly grounded in the method of working. As usual, Mr. Christie has proved himself to be a very useful assistant.

Mr. McA.Fee.

25. Mr. McA.Fee was at head-quarters with Colonel Haig until my arrival, and was employed in superintending the drawing office in Colonel Haig's absence, supplying lists of data to plane-tablers, and many other duties. When I arrived he was sent to superintend the traversers in Sheets 6, 7, 26 and 27, and besides to complete a little triangulation required in the north-east corner of Sheet 26. He is a conscientious and accurate worker.

Mr. Hickie.

26. Mr. Hickie had charge of the topography of Sheet 29, and was assisted by Balwant Govind and Sáyana Saibu. The western half of the sheet, being very thickly wooded and much intersected with ravines, the work progressed very slowly, and it was necessary to call upon Mr. S. Norman and Govind Gopál to assist in its completion. Mr. Hickie works accurately, his outturn was large,

and he ensured the general accuracy of the whole sheet by constantly changing plane-tables with his natives.

Mr. Cusson.

27. Mr. Cusson had charge of the topography of Sheet 28, having under him Gopál Vishnu and two other native Surveyors. Mr. Cusson's outturn is good, and Gopál Vishnu worked as usual very well.

Mr. S Norman.

28. Mr. S. Norman had charge of the topography of Sheet 30, except the area done by his brother. Under him were 5 native Surveyors. Mr. Norman has become a very good plane-tabler and turns out a large area every year.

Mr. C. Norman.

29. Mr. C. Norman was employed as a plane-tabler in Sheet 30 with Mukand Dinka under him, until he had to go to the Dángs with Mr. Christire. There he surveyed independently 5 omnimeter traverses, and observed rounds of angles at two trigonometrical stations. At the same time, he plane-tabled the banks of the rivers.

Omnimeter traverses.

30. It is very satisfactory to find that the omnimeter traverses in which the distances are determined by the differential subtense readings obtained on a scale by observing to the upper and lower ends of a vertical staff, give far more accurate results than were expected, in spite of the coarseness of the graduations and the inferior make of the instruments. The labour of chaining over the rugged ravines would have been immense; other routes besides the rocky river beds would have necessitated the cutting of the thick undergrowth, and the results are fully as accurate, and probably more so than chaining could have given in such a country. Other advantages of the method are that stations may be selected on prominent points, the traverse crossing from bank to bank wherever convenient, and also that the same observations that give horizontal distances will also yield the relative heights of the stations, thus affording a line of levels. Attached to this report is a copy of a table I have prepared for the distances equivalent to the differences read in the scale.

The portable still.

31. I may as well now mention that Mr. Christie and Mr. Norman report that they had a great deal of sickness among their men, and one of Mr. Christie's khalasis died of jungle-fever. They themselves however, enjoyed capital health, and they both believe that it was mainly due to their having invariably distilled all the water they used for drinking or cooking. An instance in favour of this is that one of their servants, having been frightened into using distilled water by a bad attack of fever at the outset, afterwards remained in good health in spite of his bad beginning. This all bears out the belief in the efficacy of a portable still in unhealthy jungles that I have expressed in two previous reports.

Mr. Ferns.

33. Mr. Ferns, the Head Sub-surveyor, has proved himself very useful. When I was obliged to be absent from the drawing office for the purpose of inspecting plane-tablers, he kept the office in very good order, and superintended the draftsmen and printers well. He also made all the arrangements for moving the office from Baroda to Dumas in the middle of April. He is himself a first-rate draftsman.

Table of Omnimeter Differentials and Corresponding Distances.

ARGUMENT A. B.=15,000,000.

A	100×dB/dA	B	A	100×dB/dA	B	A	100×dB/dA	B	A	100×dB/dA	B	A	100×dB/dA	B	A	100×dB/dA	B	A	100×dB/dA	B	A	100×dB/dA	B
12200	10·0	1223·5	15500	6·2	967·74	19000	4·1	789·47	22500	3·0	666·67	26000	2·2	576·92	29500	1·7	508·47	33000	1·4	454·55	36500	1·1	410·96
3	9·8	1219·5	6	6·1	961·54	1	4·1	785·34	6	2·9	663·72	1	2·2	574·71	6	1·7	506·76	1	1·4	453·17	6	1·1	409·84
4	9·7	1209·7	7	6·0	955·41	2	4·0	781·25	7	2·9	660·79	2	2·2	572·52	7	1·7	505·05	2	1·4	451·81	7	1·1	408·72
5	9·5	1200·0	8	6·0	949·37	3	4·0	777·21	8	2·9	657·90	3	2·2	570·34	8	1·7	503·36	3	1·4	450·45	8	1·1	407·61
6	9·4	1190·5	9	5·9	943·40	4	4·0	773·20	9	2·9	655·02	4	2·1	568·18	9	1·7	501·67	4	1·3	449·10	9	1·1	406·50
7	9·2	1181·1	13000	5·8	937·50	5	3·9	769·23	23000	2·8	652·17	5	2·1	566·04	30000	1·7	500·00	5	1·3	447·76	37000	1·1	405·40
8	9·1	1171·9	1	5·7	931·68	6	3·9	765·31	1	2·8	649·35	6	2·1	563·91	1	1·7	498·34	6	1·3	446·43	1	1·1	404·31
9	9·0	1162·8	2	5·6	925·93	7	3·8	761·42	2	2·8	646·55	7	2·1	561·80	2	1·6	496·69	7	1·3	445·11	2	1·1	403·23
13000	8·8	1153·8	3	5·6	920·25	8	3·8	757·58	3	2·8	643·78	8	2·1	559·70	3	1·6	495·05	8	1·3	443·79	3	1·1	402·14
1	8·6	1145·0	4	5·5	914·63	9	3·8	753·77	4	2·7	641·03	9	2·1	557·62	4	1·6	493·42	9	1·3	442·48	4	1·1	401·07
2	8·6	1136·4	5	5·5	909·10	20000	3·7	750·00	5	2·7	638·30	27000	2·1	555·56	5	1·6	491·80	34000	1·3	441·18	5	1·1	400·00
3	8·4	1127·8	6	5·4	903·61	1	3·7	746·27	6	2·7	635·59	1	2·0	553·50	6	1·6	490·19	1	1·3	439·88	6	1·1	398·94
4	8·3	1119·4	7	5·3	898·20	2	3·7	742·57	7	2·7	632·91	2	2·0	551·47	7	1·6	488·60	2	1·3	438·60	7	1·1	397·88
5	8·2	1111·1	8	5·3	892·86	3	3·6	738·92	8	2·6	630·25	3	2·0	549·45	8	1·6	487·01	3	1·3	437·32	8	1·1	396·83
6	8·0	1102·9	9	5·2	887·57	4	3·6	735·29	9	2·6	627·62	4	2·0	547·45	9	1·6	485·44	4	1·3	436·05	9	1·0	395·78
7	7·9	1094·9	17000	5·1	882·35	5	3·6	731·71	24000	2·6	625·00	5	2·0	545·45	31000	1·6	483·87	5	1·3	434·78	38000	1·0	394·74
8	7·9	1087·0	1	5·1	877·19	6	3·5	728·16	1	2·6	622·41	6	2·0	543·48	1	1·5	482·32	6	1·3	433·53	1	1·0	393·70
9	7·7	1079·1	2	5·0	872·09	7	3·5	724·64	2	2·6	619·83	7	2·0	541·52	2	1·5	480·77	7	1·2	432·28	2	1·0	392·67
14000	7·6	1071·4	3	5·0	867·05	8	3·5	721·15	3	2·5	617·28	8	1·9	539·57	3	1·5	479·23	8	1·2	431·03	3	1·0	391·64
1	7·5	1063·8	4	4·9	862·07	9	3·4	717·70	4	2·5	614·75	9	1·9	537·63	4	1·5	477·71	9	1·2	429·80	4	1·0	390·62
2	7·3	1056·3	5	4·9	857·14	21000	3·4	714·29	5	2·5	612·24	28000	1·9	535·71	5	1·5	476·19	35000	1·2	428·57	5	1·0	389·61
3	7·3	1049·0	6	4·8	852·27	1	3·4	710·90	6	2·5	609·76	1	1·9	533·81	6	1·5	474·68	1	1·2	427·35	6	1·0	388·60
4	7·2	1041·7	7	4·8	847·46	2	3·3	707·55	7	2·5	607·29	2	1·9	531·91	7	1·5	473·19	2	1·2	426·14	7	1·0	387·60
5	7·1	1034·5	8	4·7	842·70	3	3·3	704·23	8	2·4	604·84	3	1·9	530·04	8	1·5	471·70	3	1·2	424·93	8	1·0	386·60
6	7·0	1027·4	9	4·7	837·99	4	3·3	700·93	9	2·4	602·41	4	1·9	528·17	9	1·5	470·22	4	1·2	423·73	9	1·0	385·60
7	6·9	1020·4	18000	4·6	833·33	5	3·2	697·67	25000	2·4	600·00	5	1·8	526·32	32000	1·5	468·75	5	1·2	422·54	39000	1·0	384·62
8	6·8	1013·5	1	4·6	828·73	6	3·2	694·44	1	2·4	597·61	6	1·8	524·48	1	1·5	467·29	6	1·2	421·35			
9	6·7	1006·7	2	4·5	824·18	7	3·2	691·24	2	2·4	595·24	7	1·8	522·65	2	1·4	465·84	7	1·2	420·17			
15000	6·6	1000·0	3	4·5	819·67	8	3·1	688·07	3	2·3	592·89	8	1·8	520·83	3	1·4	464·40	8	1·2	419·00			
1	6·5	993·38	4	4·4	815·22	9	3·1	684·93	4	2·3	590·55	9	1·8	519·03	4	1·4	462·96	9	1·2	417·83			
2	6·5	986·84	5	4·4	810·81	22000	3·1	681·82	5	2·3	588·24	29000	1·8	517·24	5	1·4	461·54	36000	1·2	416·67			
3	6·4	980·39	6	4·3	806·45	1	3·1	678·73	6	2·3	585·94	1	1·8	515·46	6	1·4	460·12	1	1·2	415·51			
4	6·3	974·03	7	4·3	802·14	2	3·0	675·68	7	2·3	583·66	2	1·8	513·70	7	1·4	458·72	2	1·1	414·36			
			8	4·2	797·87	3	3·0	672·65	8	2·3	581·40	3	1·8	511·95	8	1·4	457·32	3	1·1	413·22			
			9	4·2	793·65	4	3·0	669·64	9	2·2	579·15	4	1·7	510·20	9	1·4	455·93	4	1·1	412·09			

Remarks.

Examples.

Differential=δ measurement on scale.
Distance = D

(1.)
δ = 15643
(A) = 15600.....(B) 967·54
43 × −6·1 = −2·62
D = 95×96
or 959 links or feet.

(2.)
δ = 9589
(B) = 96154.....(A) 15600
26·4 ÷ 9·1 = + 4·3
D= 1564·3
or 1564 links or feet.

Either A or B being taken to represent the scale measurement, the other gives the corresponding horizontal distance.
The column of differences should be headed $\frac{100 \times d\,B}{d\,A}$.

TABULAR STATEMENT OF WORK EXECUTED BY THE GUZERAT PARTY DURING THE FIELD SEASON 1876-77.

Details of Triangulation.

Observer's Name.	Instrument.	Area prepared for Topography by triangulation traversing.	No. of Stations visited.	3 Angles observed. No. of triangles.	3 Angles observed. Triangular error.	3 Angles observed. Error per mile in inches.	3 Angles observed. No. of heights.	2 Angles observed. No. of Intersected points	2 Angles observed. No. of triangles.	2 Angles observed. Error per mile in inches.	2 Angles observed. No. of heights.	Average No. of trigonometrical and traverse points per square mile.	Average No. of heights per square mile.	Remarks.
Lieutenant J. E. Gibbs, R.E. ...	Ommimeter ...	2,200*a*	39	60	In. 8·0	2·1*d*	35	95	175	3·3*g*	6	Exclusive of traverse intersected Points = 2·02	Including trgl. heights and existing levels of the B. B. and C. I. Railway, the Bo. T. and Lg. Party and the Irrigation Department, there will be an ample number.	*a.* Total area prepared for topography, exclusive of Dangs, *see* paragraph 3 of Lieutenant Gibbs' report. *b.* Total area in Dangs ready for topography on 4-inch scale. *c.* One of these fixed only by interpolation. *d.* Average of 37 common sides. *e.* " 4 " *f.* " 7 " *g.* " 60 " *h.* " 1 " *k.* " 28 "
Mr. C. H. McA. Fee	6-inch Theodolite by T. and S.		10	10	14·4	1·1*e*	5	5	8	20·5*h*				
" A. Christie	6-inch Theodolite by T. and S.		4	2										
" do.	Ommimeter ...	288*b*	34	40	11·5	3·6*f*	30	56	132	22·6*k*	2			
Mr. C. A. Norman . .	Ommimeter ...		2*c*											
Total ...	.. ..	2,488	89	112	.	.	70	156	..	..	8			

Details of Topography.

Name.	Area surveyed in square miles.	No. of plane-table stations per square mile.	Remarks.
Mr. A. D'Souza ...	166·72	13·3	Besides examination of Bhau G's work.
" J. Hickie	205·63	11·9	Besides examination of Balwant G.'s and Sayana S.'s work.
" G. D. Cusson ..	174·93	9·3	Besides examination of Gopál V.'s, Ganesh B.'s, and Balwant R.'s work.
" S. F. Norman ...	242·86	7·1	Besides examination of Raoji N.'s, Mukand D.'s, Govind G.'s, and Virapa P.'s work.
" C. A. Norman ...	124·79	9·9	
Gopál Vishnu	200·49	12·1	
Bhau Govind	201·75	15·4	
Ba want Govind .	134·90	21·1	
Ganesh Bápuji, 1st	99·9	25·0	
Mukand Dinkar ...	61·99	14·0	
Govind Gopal	38·26	17·3	
Balwant Rajaram ...	158·84	11·7	
Sayana Sadhu ...	166·84	17·4	
Virapa Pirgji	18·95	18·6	
Raoji Narayen	165·17	15·1	
Total and Average ...	2019·22	13·0	
D D Overlap ...	31·44		
Total ...	1987·78	Within graticule.	

Details of Traversing.

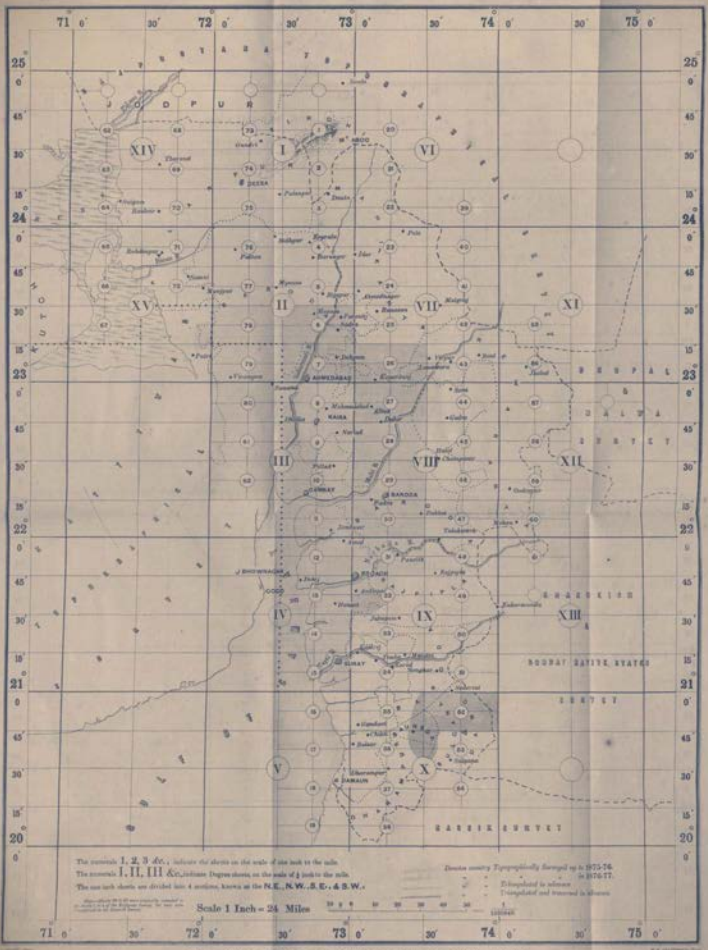
Name.	Instrument.	Linear miles of traversing.	Average error per 1,000 links.	Average angular error per station.	Remarks.
Lieutenant J. E. Gibbs, R.E. ...	Ommimeter ...	59·81*c*	0·61	In. 9·0	*a.* Main traverses which have been computed in "systems" so as to harmonize—one traverse by Sitaram Yeshwant having been included in a "system."
Mr. A. Christie	6-inch Theodolite by T. and S.	137·77*d* 15·30*b*	0·67	12·3	*b.* Baroda State boundary traverses.
" C. A. Norman	Ommimeter ...	19·04*c* 56·41*c*	0·84 4·79	4·8 14·7	*c.* Ommimeter traverses, *i.e.*, those in which the distances between stations were obtained by subtenses instrumentally.
Ganesh Bápuji, 2nd ...	6-inch Theodolite by Cook and Sons.	42·07 228·149	1·66	18·3	*d.* Besides three traverses that would not close—
Ganesh Bápuji, 1st ...		3·92 44·026	1·11	12·4	Total number of traverse stations fixed this year—
Ramchandar Vishnu ...		97·96 84·2 *b*	1·26	14·1	In sheets 26, 27, 6 and 7 ... 4,296
Shivrám Narayen		13·82*d*	0·13	20·7	In sheet 52 (Dangs) ... 671
(*Leveling Party.*)					In published sheets (boundary traverses) ... 1,374
Damodhar Ramchandar ...		23·24 21·896	2·78	7·0	Total ... 6,041
Sitarám Yeshwant		8·350 71·33 124·956	1·70	10·3	
(*Revenue Survey*)					
Sivaji Nanaji		170·17 76·078	0·92	17·8	
Kubar Parbhudass ...		170·85 5·795	1·27	22·0	
Jugal Mansukhram ...		255·74	0·62	10·8	
Parbhu Kisor		217·55 14·886	0·64	16·2	
Total ...	.....	1348·08 616·505			
Grand Total ...	.....	1964·58	miles.		

SEASON 1876-77.

At Milan itself, after my arrival there, it snowed for about eight days with but some occasional

GREAT TRIGONOMETRICAL SURVEY OF INDIA

INDEX CHART OF THE GUZERAT TOPOGRAPHICAL SURVEY


71 6' 30' 72 6' 30' 73 6' 30' 74 6' 30' 75 6'
25 24 23 22 21 20
I II III IV V VI VII VIII IX X XI XII XIII XIV XV
AHMEDABAD
BARODA
BROACH
SURAT
DAMAUN
BOMBAY
KAIRA
CAMBAY
GOGO
BHOPAL
DHOLKA
DISTRICT
KATHIAWAR
BOMBAY NATIVE STATES
RANN
RANN SURVEY
The numerals 1, 2, 3 &c., indicate the sheets on the scale of one inch to the mile.
The numerals I, II, III &c., indicate Degree sheets, on the scale of ½ inch to the mile.
The one inch sheets are divided into 4 sections, known as the N.E., N.W., S.E., & S.W.
Scale 1 Inch = 24 Miles
Districts recently Topographically Surveyed up to 1875-76.
Do 1876-77.
Triangulated in advance
Completed and traversed in advance

Photozincographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Doon, November 1877.

Extract from the Narrative Report, dated November 28th, 1877, of E. C. Ryall, Esq., in charge Kumaon and Garhwal Party.

3. On the 9th March my camp left Dehra Dún for Almorah; I myself followed on the 14th by dák and rail, with a view to completing my preparations at that station. It was my intention to move up the party from Almorah as early as possible, so that I might be enabled to accomplish the survey before the setting in of the rains. On the 25th March the whole party was got together at Almorah, and by the 1st April it was fully equipped for its northward journey. Owing, however, to heavy rains, I did not find it expedient to push on till the 10th April. On that day Mr. J. Peyton left for the Byans Valley, which lies to the northeast of Kumaon, bordering on Nepal. Messrs. Pocock and Warwick left on the same day for the Dharma Valley, lying contiguously to the west of the Byans Valley; I myself, together with two Native Sub-Surveyors, marched for the Upper Jowar Valley on the 14th.

4. About four days after my departure from Almorah, clouds and rain again troubled us. At Bageswar, my second march out of Almorah, I received intimation that Mr. Warwick had fallen ill; I therefore directed him to join my camp for medical treatment, which he did on the following day. This circumstance at the time gave me no little cause for anxiety; however, all went fairly well with him afterwards, though he was ailing more or less throughout the season.

5. The winter of 1876-77 proved to be the severest known for many years past amongst these hills; the spring was wet and cold, and felt quite wintry. When I left your head-quarters, Dehra Dún, I was in hopes that the wet weather would not last long; it continued, however, with few intermissions till the 8th June, the most noticeable break-up to that time being from the 9th April up to the 17th. After the 8th June, there occurred but few falls of snow on the higher mountains, the heaviest being between the 2nd and 4th of July, when the passes leading into Thibet became almost impracticable.

6. Mountains which in ordinary years had their snow line at the end of April at an elevation of 12,000 feet above sea level, were mantled with snow down to 9,000 feet, and valleys, which at that time of year used to be clear of snow up to 10,000 feet, were literally choked with snow down to 6,000 feet, this accumulation in the valleys being caused by snow drifts and avalanches from the mountain sides.

7. Consequent on the prolonged wet weather, the inhabitants of the upper valleys found it impossible to make for their summer homes till very late in the season; the usual time for their migration northwards being about the end of April. So, when the Survey Parties were marching for their ground, they met these people, from whom alone they could expect assistance, camped about the lower valleys. This state of things made matters look very inauspicious. I had great fears lest the monsoons should come down upon us before the people could be induced to move up.

8. My assistants had rather difficult people to deal with in the Bhoteas of Dharma and Byans. They made frequent efforts to induce these people to move, and only succeeded after considerable delay just in time. My case, however, was seemingly worse. On my line of march I met the inhabitants of the Upper Jowar or Milam Valley loitering about the banks of the Sarju and Ramganga. These people possess an advantage over those of the other Bhot Pergunnahs of Kumaon and Garhwal, for they own intermediate homes in Munshiári, a district lying at the foot of the Milam Valley. Here numerous villages belong to them, and extensive fields are cultivated for them by Hindu tillers, permanent residents of the place. These villages being on an average not over 6,000 feet, the inclemency of the weather could not have kept them away. The cause I ascertained to be the raging at Munshiári of an epidemic, locally known as "mahamari" or "gola," which had carried off many of the Hindu inhabitants of these localities; but at the time I got there, 20th April, the disease had greatly abated. Nevertheless, the villages were entirely deserted by their Bhotea inhabitants.

9. As I had allotted to myself a large share of the topographical work, as well as the extension up to the frontier of Thibet of a series of triangles, I could not afford to lose much time, and it became clear to me that I must push through in spite of the ill-conditioned state of the valleys and passes on ahead. I accordingly summoned the influential men amongst the Bhoteas, whom I met along the Sarju and Ramganga, and they readily obeyed my call. They promised to take their people up to the Milam if I would show them the way; but under any circumstances they said they could not make a move for at least another twenty days. Meanwhile I undertook to clear the way.

10. In anticipation of meeting with some road-cutting difficulty, I engaged at Almorah nine professional road-cutters; these were, however, far too small a number for the heavy work before them, so I engaged sixteen other men from amongst the Hindus of Munshiári. On the 23rd these men began their work, and by the 29th they had made sufficient progress to enable me to move on. After collecting supplies for establishment and coolies, I commenced my journey northwards, and on the 6th May my detachment succeeded in getting into Milam village, catching up the road-cutters within a few miles of that place. There are in all twelve villages in the Milam Valley, and I found most of the houses in them burried in snow. The journey up was harassing, aggravated by falls of rain, sleet and snow. Except in those parts of the valley which were open, and consequently more exposed to the influence of the sun, I found it difficult to get a spot for pitching the camp on without clearing off the snow. At Milam itself, after my arrival there, it snowed for about eight days with but some occasional

breaks lasting for a few hours each day. I had a mistaken impression at the time that once over the Unta Dhurra Pass, the greater portion of my snow difficulties would be at an end, and I directed that the road-cutting establishment should press forward and make efforts to clear that Pass. They failed twice, the recent falls of snow greatly crippling their movements; at the third attempt they succeeded in getting over. They were at this work for more than a fortnight. In the meanwhile I carried on the topography of the Milam Valley as far as that was practicable.

11. On hearing of the opening of the Unta Dhurra Pass, 17,350 feet above sea level, I arranged to get across; and on the 30th May I resumed my march upwards. Though only about 13 miles away, I did not succeed in crossing the Pass till the fourth day. Now were left before me two more Passes, not quite so formidable as the first, but very trying notwithstanding.

12. On the 8th June I succeeded in getting into Hundes, as that portion of Chinese Thibet lying to the north of Kumaon and the two Garhwals is called. I was much disappointed, however, at being greeted on the southern face of the Balchdhurra Pass, leading into Thibet, by two Hunias.

13. To go on with instruments, I was bound to give some plausible reason; so I explained to the two Hunias, who were about to return at once to Daba, that my object was to survey the northern limits of British territory, which I found impossible to do from the southern faces. Before their departure I made them quite happy with gifts of rice, ata, &c.; one of them turned back carrying my message to the Daba Jongpan, as the Ruler of these parts is called, and the other followed me the next day accross the Pass. Two days after this, I reached and observed at my first station, Chilamkurkur hill-station. On my return from this station I was met by ten or twelve other Hunias, despatched to my camp by the Jongpan. They brought me a message conveying a mild reproof at my entering into the district, but added that as I had come, I was at liberty to go on with what I was doing, on the condition, to which I readily agreed, that I should not cross the Sutlej. These men stayed with my camp several days, helping in pitching my tent and bringing in supplies of fuel. In time others from distant grazing grounds brought in sheep, milk and butter for sale. My escort of a dozen then gradually dwindled down to four; these again left me on the 2nd July, when I re-crossed the Balchdhurra Pass into British territory.

14. I was in all about twenty-four days in Hundes, during which time I succeeded in observing at sixteen stations, from which I took angles to about 45 distant peaks, whose distances average about 60 miles; about thirty other peaks were also observed to at an average distance of about 30 miles. About half the number of points have vertical angles observed to them.

15. After doing all I could in Hundes, I hastened back to form a connection between the work there and the base on the Unta Dhurra ridge. As I had succeeded in laying down points which circumscribe a very large area of country, roughly estimated at about 13,000 square miles, I thought it would be as well to double the series running up the Unta Dhurra gorge, the sides there being necessarily very short, and some of the angles rather acute. I, accordingly, on my return towards Milam, undertook this work, and by the 25th July accomplished it.

16. In 1874, while triangulating up the Milam Valley, I was unable, owing to heavy rains and other causes, to observe the third angles at some of my stations. These were six in number; including these, the total number of points visited during the season is 27; the average height of them is about 17,800 feet, the highest being a little short of 19,600 feet.

18. When I returned from my triangulation, I finished the topography of the Milam valley. I also topographically surveyed the eastern range of the northern valleys, making at the same time a reconnoissance of about 70 square miles in Hundes. The interior details of the northern valleys were filled in by my native Sub-surveyors. The area of topographical work done by me is 640 square miles, which includes 120 square miles of reconnoissance in Hundes.

19. The length of the series carried up by me is about 52 miles, and the area triangulated, exclusive of that embraced by distant points, is about 560 square miles.

20. On the 4th August I left the Milam valley for Almorah, where I arrived on the 15th, shortly after which Messrs. Peyton and Warwick joined me.

Mr. Pocock came in about the end of August, and the native Surveyors about the 20th September.

21. I shall now proceed to report on the work of my Assistants. I have in some of the foregoing paragraphs touched upon a few difficulties which were common to every member of the Party, so they need not be recapitulated here.

22. Mr. Peyton being my most experienced hand, I directed him to take up the survey of the Byans valley which had not in it a sufficient number of trigonometrically-fixed points to make it safe to give it up to a less experienced Surveyor. Moreover, I supplied him with a 7" theodolite, so that he might lay down some points in the north-east corner of the Byans valley should he find it necessary to do so. He was further instructed to obtain, if possible, some bases on the frontier, with a view to laying down some trans-frontier points from them. Mr. Peyton, while carrying on a series of triangles up the Byans valley, succeeded in laying down numerous points in it; but he found it impossible to obtain any base on the ridge which overlooks the trans-frontier country. The triangulation executed by him extends over an area

of 310 square miles; his topographical work amounts to 502 square miles, executed on the scale of half an inch to a mile, including 67 square miles of reconnoissance. I consider Mr. Peyton to have turned out an excellent field season's work

23. I beg to submit here some notes by Mr. Peyton on his work, and the topography of the Byans Valley:—

"The weather last winter was exceptionally severe throughout the northern districts of Kumaon. Hills rising to only 12,000 feet were perfectly white to about two-thirds of the distance from the summit to the base. The quantity of snow on the mountains, which was continually increasing, held out a dismal promise for my chance of surveying the higher regions, and caused sufficient delay to disarrange my plans to enter Byans at an early part of the summer. The passes across the watershed between Byans and Thibet, which are generally open about the first week in May, were inaccessible to travellers from the south till a much later period; for I met the first batch of traders from Kumaon proceeding to Taklakot about the middle of June, and even then many portions of the high road to Thibet were blocked with snow; the drifts were deep, and a few days later, when I was approaching the Lipu Lek pass, all trace of the path was obliterated. This long continued spell of bad weather all through the summer is in these hills highly exceptional.

"My camp reached the Nirpania pass (11,257 feet) leading into Byans on the 25th May, and here I halted for a week, anxiously looking out for a break in the weather, for snow was still falling, and towards the higher of the two Nirpania stations it lay very deep. This is the only route up the Byans Valley, all communication with which is cut off in winter, when much snow lies on the Nirpania range; and drifts on the road side 25 feet deep are said to be common.

"In June there were only eight clear days, when I got good views of the mountain peaks far and near. On the 3rd July, when I was in the Kuti Valley, there was a snow-storm accompanied by a cold raw wind, which repeatedly veered round the compass. The entire valley, for six days after the snow fell, was perfectly white down to the rocks on the river. In July I had only five days of clear blue sky, when the mountain features generally blurred by fog and mist, were distinctly visible. I was greatly surprised to find that, in the Kuti Valley, where I was fairly behind most of the great snow and rain-collecting mountains, there was no change in the climate; the weather was seldom fine for more than a couple of hours in the morning, and I rarely returned dry to my tent from an excursion to any of the mountains above 12,000 or 13,000 feet.

"As soon as the passes into Thibet are open, there is considerable traffic on the main road through Byans, and several parties of Thibetian traders travel down to Kumaon with flocks of sheep laden with salt and borax. At a much earlier period, or as soon as the snow disappears from elevations below 11,000 feet, the Bhoteas return from their winter trip to the lower hills, and proceed to their villages in Byans.

"I made inquiries regarding my ability to penetrate farther than our territory, as far at least as Taklakot, which is a place of some importance, lying on the trade route between Kumaon and Thibet; and all I learnt was discouraging and against my chance of going there. I made the Taklakot officials presents of brandy, goats, and cloth, and they accompanied me as far as the pass, but nothing would induce them to concede the point relative to the extension of my journey to Taklakot.

"There is a very rough road on the northern side of the pass of Nirpania leading into Byans, very rocky and difficult,—a staircase, as it may properly be called, overhanging through its whole extent a series of frightful precipices, nearly perpendicular, where fatal accidents have often taken place, which the guides never fail to relate with every appalling circumstance. It gets worse as you descend to the valley, and being quite unprotected as it leads along bluff faces of cliffs by rocky steps and rotten planks, the sense of insecurity is very great. The mountains here are intersected by a network of narrow valleys, the opposite faces of which approach each other so closely at some points, that it is possible to shoot an animal, or even throw a stone across the gorge.

"The Byans Valley communicates with Thibet by three routes, the principal and earliest open to travellers is called the Lipu Lek pass. The extent of snow which the traveller will encounter depends entirely on the season; it varies from two to seven or eight miles, but in moderate weather this is a very easy pass indeed; on the 21st June we had a bright morning after a cold night at the foot of the pass, where the camp was pitched on a narrow plain, 15,000 feet above the sea; making an early start, we followed a valley to the south-east, the path lying over beds of recent snow; a little after sunrise when we were not far from the summit a cold wind was blowing, which made the cold already intense, almost unbearable; for the iciness of a Thibetian breeze, especially at these elevations, is something which only those who have experienced it can imagine. I was moreover ascending the pass on its shady side, and so, until I reached the top, was deprived of any warmth to be got from the sun's rays. From the pass there is a fine view of the Thibetian hills, framed as it were by the vast shoulders of the snowy range. For a short while the mist rising from the valleys had nearly blotted out the lower landscape, but the white, and in some places purple, outline of Nammu Nanghil (Anglice: youngest sister of the king of Heaven, 25,200 feet) was sharp against a clear sky; the plain beneath looking very faint till the sun beat on it, when it appeared of a reddish colour, without a tree or a speck of green anywhere. The main chain of the frontier reaches its greatest elevation and true central point in the mountain mass (22,000 feet) which towers over its off-shoots above the sources of the Kuti river. The southern spurs of this range descend to the main valley in long-serrated ridges, marked by cones, needles, and spires, which shoot up into the sky even higher than the northern peaks, and terminate abruptly in a line of precipices and crags which skirt the river.

"The highest mountain on the east watershed of the Kali is Nampa (23,350 feet), with steep snow beds cut into vertical ridges, and great towers of rock shooting out from below, between which are several extensive glaciers. With the exception of these glaciers, and that of Mang Shang, east of the Lampia Lek pass, there are very few of any size on the southern side of the main range. The Mang Shang glacier descends from the snow plains between two beautifully white mountains in a magnificent sheet, remarkably uniform and yet very steep. On the Dharma side the largest glacier, called 'Sumzurkchan Kagal,' is about seven miles in length, and occupies a considerable portion of the lateral valleys south of the village of Kuti.

"There are seven villages in Byans, all *fac similes* of each other: Garbia probably the largest, with a population of 500. With the exception of some half a dozen houses, built in the style of a Swiss Chalet, they are all low and small, the building materials being for the most part furnished by the cedars that cover the Shialek range south of Garbia. The village stands on the right bank of the Kali, opposite the valley formed by the Tinkar stream which comes from Nepal, the ground in some places being covered with accummulations of alluvium and in others cut into cliffs by the river. The great characteristic is sterility; hill and valley, on the whole, presenting an expanse of stony waste. The northern ranges average from 16,000 to 22,000 feet, the valleys being 9,000 to 12,000 in the agricultural, and 11,000 to 14,000 in the pastoral districts. The main valley through which the Kuti, the larger of the two streams which traverse the district, flows, at its broadest part scarcely widens to more than one hundred yards, and is shut in by the towering peaks that run north and south respectively to Hundes and Dharma. The total length of the valley is 31 miles, and the highest peaks to the north have an elevation of more than 22,000 feet.

"The Bhoteas in these high regions are a sturdy race of hillmen, with no caste prejudices, for they will eat game of all kinds, and drink to any extent. They are principally engaged in agriculture, and breeding sheep and goats; all their clothing is made by hand looms, the wool procured from their own sheep. At all the villages I visited, the women seemed industrious and happy; their staple trade is the weaving of woolen

blankets, or plaids of bright colours. They also make fancy scarfs for the waist and other small articles of the kind; and occasionally act as coolies when there is a lack of men. At Garuia the Tartar physiognomy is by no means predominant, and although the noses are generally somewhat broad and the cheek bones large and prominent, yet I saw some faces which in any country would be acknowledged to be pretty and expressive. I found the men always faithful to their engagements, and many of them in their attendance on my camp went through great hardships and inconveniences, roughing it on high mountain tops without shelter of any kind, exposed to sleet and snow, and often to a cold cutting wind."

24. Mr. Pocock, who succeeded so well on a former occasion in accomplishing the survey of the Mana Valley,—a very lofty region towards the north-west of British Garhwal,—was deputed by me to take up the northern portion of the Dharma Valley, which appeared to me from all accounts to be equally lofty and far more craggy. He was not able to begin work till the first week in June; the enormous quantities of snow he had to go over considerably retarded his progress, but by the 15th August he contrived to finish his work. He was only employed in topography on the scale of half an inch to a mile, and his out-turn is 294 square miles. As the Byans Valley lies contiguous to the Dharma, the difficulties met with by Mr. Pocock, arising from inclemency of weather were similar to those encountered by Mr. Peyton; perhaps more aggravated, owing to the greater altitude he had to work in. The highest plane-table station of Mr. Pocock is about 19,000 feet, average about 16,500 feet.

25. To Mr. Warwick I allotted the southern portion of the Dharma Valley. He also experienced the vicissitudes of weather complained of by Mr. Peyton, but as he was not employed in very lofty ground, he felt them to a lesser degree. Mr. Warwick, as I have stated, fell ill at the very out-set: he was more than 20 days ill, but recovered sufficiently at the end of that time to march off to his ground. He suffered more or less throughout the season, but managed with perseverance to get through his share of the work, which amounts to 163 square miles of topography on the half-inch scale.

27. The entrance into the Milam Valley is through a stupendous gorge, overhung by large masses of granite precipices; this gorge is about 12 miles in length, and the road through it is for the most part a mere series of narrow steps built along the faces of steep hill sides or rugged precipices, and where this is impracticable, planks leading from one ledge of a precipice to another are laid across. After the first 12 miles the country becomes more open. The mountains here are composed of three different kinds of rock; the lowest formation is granite, of which all the most lofty peaks are composed; the second is a hard slate; and the third and highest is a hard crystallized limestone. The mountains are not very precipitous near the sides of this portion of the valley. The open part of the Milam Valley is about 14 miles, up to the village of Milam. Here the valley splits up into two; the one to the west is occupied by an extensive glacier running down to within two miles of the village; the other might be called a narrow gorge extending up to the very watershed line on the Unta Dhurra. The formations in these two valleys are the same as those found in the open parts of the valley below. At the foot of the Unta Dhurra range lies a glacier about 4 miles in length, and owing to this glacier the approach to the pass is extremely difficult. The Unta Dhurra pass is the most difficult of all the passes in Kumaon and Garhwal.

28. The two northern valleys, owing to the absence of a general name for them, might be called the Girthi and Kiangur valleys. The drainage of these valleys falls into the Dhauli river in the Niti valley. The Girthi valley is bounded on the north by sheer cliffs of limestone rising to over 19,000 feet; on the south it is belted by peaks and ranges averaging over 21,000 feet. The highest parts are composed, to all appearances, of granite, and the lower of limestone in a semi-crystallised state. The Kiangur valley is entirely composed of this limestone; its southern slopes are precipitous, but the northern slopes, though lofty, are for the most part undulating, and present a view for 15 miles of pleasing softness when compared with the ruggedness of the southern ridges. These slopes are richly covered with verdure up to about 15,000 feet, and at their bases a description of furze is found to grow luxuriantly, the roots of which make capital fuel. At the time of my passage through, the entire valley was covered with snow; and it was only on my return from Hundes in July that I was greeted with all the bloom of spring, though it was past midsummer.

30. Before concluding this, I would beg to bring prominently to your notice the services rendered by Dhannu, Jangpani of the village of Burphu in the Milam Valley, and of Rapti in Munshiari. On previous occasions Dhannu has rendered very good service as head manager of the camp, in procuring supplies and rendering himself generally useful. This year it was chiefly due to him that I was able without much trouble to make the extensive preparations which were necessary for conducting supplies, first over five marches in the Milam Valley, and then over eleven marches of sterile and barren country.

He is a man possessing extensive influence and tact.

32. During the conduct of the field operations in Kumaon and Garhwal, Mr. W. Todd was left in charge of the mapping department of my office. Of the Dehra Dún Survey on the scale of four inches to the mile, the following maps have been completed, *viz.*, Nos. XXIII, XXX, XXXIII, XXXIV, and XL; of the remaining sheets of the same survey, Nos. XXIV, XXXI, XXXII, XXXVIII and XXXIX require typing of names to complete them for photozincography. The drawing office helped in outlining sheets XXIV and XXXII, and in both outlining and shading sheet XL.

33. The outlining of the four sheets of the Jaunsar Báwar Survey, on the scale of two inches to the mile, has been done, with the exception of those portions surveyed by the Forest Department.

34. The two sheets of the large scale map of Dehra and its suburbs (twelve inches to the mile) have been outlined.

35. The reduction of the Dehra Dún maps from the scale of four inches to a mile to that of one inch to a mile is in progress.

36. *Pari passu* with the supervision exercised by Mr. Todd in the mapping work, he was employed for about a month in drawing up a narrative of the Mullah's explorations.

Mr. Kinney joined the office about the middle of May, and rendered Mr. Todd great assistance by taking up the shading of six and a half sheets of the large scale, Dehra Dún Survey. The progress made in the drawing work is very creditable to Messrs. Todd and Kinney.

KUMAON AND GARHWAL SURVEY,

Tabular Statement of out-turn of work, season 1877.

Details of Triangulation.

Observer's Names.	Area of triangles in square miles.	Number of stations visited.	Number of triangles of which all three angles have been observed.	Number of intersected points fixed.	Number of points whose heights have been determined.	Average altitude in feet above sea-level of stations visited.	Remarks.
E. C. Ryall, Esq. ...	560	27	26	75	57	17,800	Exclusive of 13,000 square miles embraced by intersected distant, snowy peaks in Thibet. Length of series of triangulation = 52 miles.
Mr. J. Peyton, ...	310	12	9	21	26	13,090	The series of triangulation executed = 18 miles in length.
Totals ...	870	39	35	96	83	...	

Details of Topography, Scale, 1 inch=1 mile.

Name.	Area surveyed in square miles.	Average number of intersections per square mile.	In feet above sea-level: Average height of ground surveyed.	Average height of plane-table stations.	Maximum height of points visited.	Area of glaciers in square miles.	Remarks.
E. C. Ryall, Esq. ...	640	0·32	19,000	15,000	19,600	33	Includes 120 square miles of reconnoissance.
Totals ...	640	0·32	19,000	15,000	19,600	33	

Scale 1 inch=2 miles.

Names.	Area surveyed in square miles.	Average number of intersections per square mile.	In feet above sea level: Average height of ground surveyed.	Average height of plane-table stations.	Maximum height of points visited.	Area of glaciers in square miles.	Remarks.
Mr. J. Peyton, ...	350	0·20	18,000	13,700	16,500	10	In British Territory.
	85						In Nepal.
	67						Reconnoissance in Nepal.
„ J. S. Pocock, ...	294	0·30	18,500	15,500	19,000	39	
„ R. F. Warwick, ...	163	0·50	12,500	11,000	14,200	5	
Totals ...	959	0·33	16,333	13,600	...	54	

N. B.—Total of Topographical work executed on both scales 1,599 square miles.

E. C. RYALL,

Asst. Supdt., G. T. Survey of India,
in charge, Kumaon and Garhwal Party.

Extract from the Narrative Report, dated 23rd August 1877, of Captain A. W. Baird, R.E., in charge Tidal and Leveling Operations.

2. In June 1876, I availed myself of three months' privilege leave and went to England. Prior to my departure, I was informed that it was most probable I should have to remain there to finish off the reductions of the tidal observations in co-operation with Mr. Roberts of the Nautical Almanac Office. I had to settle, therefore, the work for the next field season before I left. In the former season two detachments of the party were at work, carrying on different lines of levels simultaneously; it was of course only necessary for me to arrange for one detachment to be at work, should I not return in time to take the field.

Only one detachment of the party to carry on leveling.

3. Major (now Lieutenant-Colonel) Haig took charge of the party on my departure. I drew up a memorandum for his information, giving all the details of the lines of levels, and the branch lines which should be executed so as to connect irrigation, railway, and other levels. With this memorandum for his guidance, Mr. Rendell (who had charge of the detachment) had no trouble in carrying out the work required.

6. Mr. Rendell reports:—

"My first duty was to make enquiries and search for the Irrigation bench-marks round about Sánand. I spent a week in useless search, although I had a map by me shewing their position. This was due to the fact that the majority of the Irrigation bench-marks are situated on the roots of trees, which I was not aware of at the time; I looked for something more substantial: however, on communicating with Major Haig, he sent me a complete list of the bench-marks I required, with a full description of each, and which contained the names of the village officials to whose care they were handed over. With this before me, I found no difficulty in connecting a number of Irrigation bench-marks extending over Sheets 80, 81, 8, and 9 of the Guzerat Survey."

Difficulty in recognising Irrigation Department bench-marks.

7. After completing this, Mr. Rendell marched to Mehmadabad, where he arrived on the 23rd December. He then connected Jinjhar H. S. with the Mehmadabad bench-mark by a branch line about 6 miles long, and afterwards commenced work on the main line of levels which was being carried along the railway line. By the 2nd January he reached Ánand Railway Station, and then drove a branch line along the railway from Ánand to Páli, a distance of 32 miles, and connected Páli and Poeda stations of the Great Trigonometrical Survey triangulation.

Work commenced on main line and branch to Páli, &c.

8. The work on the main line was recommenced on the 24th January, and by the 11th February the main line had been carried as far as Wásad. From this a branch line was taken to Cambay, and a Great Trigonometrical Survey bench-mark was embedded near the town, and the Trigonometrical Station (Cambay Factory) was also connected. This branch line was 33 miles in length, and along it 20 pucka points or bench-marks were connected.

Branch line to Cambay.

9. The main line was then continued as far as Baroda, where a bench-mark was laid down at the Railway Station, and another in the Cantonment, and several pucka points were also connected in Baroda, such as the steps of the dák bungalow, the pavement at the bottom of the clock tower, &c., and also the top of the clock tower, being a Great Trigonometrical Station. The heights of the points fixed at Baroda were supplied to the Executive Engineer for Irrigation at Baroda, to enable him to refer all his levels in future to mean level of sea.

Pucka points connected at Baroda.

10. The main line was then continued, and on the 23rd February had reached Meagám, where a branch line was carried to Sidpur H. S., a distance of 30 miles, 23¼ of which extended over the narrow gauge Railway of his Highness the Guicwar, which goes to Dabhoie. Bench-marks and pucka points were connected *en route*.

Branch line to Dabhoi and Sidpur H.S.

11. By the 9th March the main line had been carried as far as Broach. Of the work on the main line beyond this, Mr. Rendell reports:—

"Owing to a good portion of the Nerbudda bridge (nearly half) having been washed away during the previous monsoon, I anticipated great difficulty in carrying my line of levels across the river, which at this point is nearly one mile broad. I found that a temporary structure had been erected over which trains passed at a very slow rate of speed, this structure being connected with the portion of the bridge that remained standing, by a diversion having a decline of something like 1 in 12. One or two pucka points on the north and south banks of the river were also fixed, and their heights notified to the Railway Engineer in charge of the bridge, who was desirous of obtaining accurate data to start from, in connection with the new bridge which is about to be constructed.

Levelling over the Nerbudda, the Railway bridge being partially destroyed.

Surat was reached by the end of March, and several bench-marks in the vicinity of the town were connected.

12. In continuing the main line, several of the Irrigation Department levels in connection with the Tapti project were connected between Ankleswar and Saehin.

Irrigation levels of the Tapti project connected.

13. From a point about 3 miles south of Bulsar a branch line was run to Parnera H. S., a principal station of the Northern Concan series, and by 28th April the main line was closed for the season at Damaun Railway Station; a branch line was carried from this to the town of Damaun, a distance of 6 miles, where a Great Trigonometrical Survey bench-mark was laid down.

Main line closed.

14. The operations were carried on throughout by two independent levelers according to the rigid rules in force in this Department. Mr. Rendell reports:—

General execution of the leveling.

"In no case was the discrepancy between the two instruments allowed to exceed ·006 of a foot; and, indeed, instances are rare where a difference of ·005 of a foot was allowed to pass without repeating the observations."

The difference between the closing results of the two levels was 0·090 foot, and the greatest difference at any end of any section during the season was 0·128 of a foot, which was at 14¼ miles from starting.

Comparision of the staves.

15. A comparison of the staves with the portable standard bar was made four times during the season, *viz.*, at Sánand, Meagam, Surat, and Damaun.

Height at Railway Stations connected.

16. The heights of the rails opposite the booking offices of 35 Railway Stations were ascertained, and the average error of the heights as given by the Railway authorities is ± 5·1 feet. The greatest error was at Palej, *viz.*, + 8·0 feet, and the least at Broach + 2·5 feet. At Broach the error of the Railway height is 2·5 feet, and at Ankleswar it is 6·2 feet, and the distance is only 5½ miles; this would give an error of 0·67 foot per mile. Similarly, between Bulsar and Dungri, also a distance of 5½ miles, there would be an error of 0·67 foot per mile, but errors of this magnitude are of course exceptional.

Outturn of work during field season.

17. The following statement shews the amount of leveling executed by the party.

Double leveling, main line	183½	miles.
ditto, branch line	174½	„
TOTAL ...	358¼	„
Single leveling loop line	16¼	„
Number of Gr. at Trigonometrical Stations connected ...	16	
Number of Great Trigonometrical Survey bench-marks embedded and connected	31	
Railway heights connected	39	
Number of Irrigation heights	40	
Number of other pucka points duly inscribed and connected	180	

Loop line, Sánand to Ahmedabad.

19. As the levels supplied to the Officer in charge, Guzerat Party, by the Executive Engineer, Ahmedabad, for incorporation in the Guzerat maps, would not stand any single correction, that is, the correction applied to one set of levels would not suit another set which had one station in common, I sent up a leveler and a few men to run a loop line from Sánand to Ahmedabad, and pick up the points as given in the list of levels in question. This loop line emanated from a point at Sánand, connected with the Great Trigonometrical Survey bench-mark there, by double leveling and closed on a point at Ahmedabad, also connected by double leveling with the Great Trigonometrical Survey bench-mark at Ahmedabad. The closing error of the single line was 0·044.

Mr. Rendell's services.

21. The out-turn of leveling for the season I consider excellent, and Mr. Rendell deserves much credit for this. I take this opportunity of bringing Mr. Rendell's services prominently to notice. He has been four years in his present grade in the Department. In August 1875 I also reported favorably on him, with a view to his being promoted; but the vacancy in the next higher grade at that time was, I believe, absorbed on account of reductions in the Survey Department.

Work in the office during recess.

23. Since coming into recess quarters, the duplicate Sheets have all been completed and brought up. The description of bench-marks and all pucka points connected have been made out in dupliente, with sketches of the points, where necessary, to accompany the level sheets. The abstract of heights, and computation of unit corrections, also table of comparison of Great Trigonometrical heights determined trigonometrically and by spirit-leveling, have been completed. Similar tables for Railway heights and charts, shewing the routes of leveling in detail, are all nearly completed; and the forms for the preservation of the stations have been filled up and handed over to the different authorities, and receipts obtained for the safe custody of the stations. In fact the whole work in connection with the leveling operations will in a few weeks have been completed and despatched to the head quarter office.

Extract from the Narrative Report, dated 17th October 1877, of Captain W. J. Heaviside, R. E., in charge No. 1 extra party.

(1). The field season of 1876-77 was commenced by this party more than usually late; in the first place because the first station for observations was Vizagapatam, which is exposed to the full force of the north-east monsoon and where clear nights for observing were not to be expected until January; in the second place owing to the heavy nature of the computations of the previous season's work, which it was considered most desirable to clear off before leaving recess quarters. Moreover, I had been warned that I might have to take up latitude observations, towards the close of the field season, with one of the zenith sectors, and as these instruments were new to me, while my colleague Captain Campbell was well acquainted with both of them, I availed myself of the opportunity of his presence to have some practice with them before taking the field. Both instruments were put up with Captain Campbell's assistance and their peculiarities pointed out by him, after which I had one of them carried out to the south-west station of the Bangalore base line and took observations there on two or three nights, subsequently reducing the observations according to the forms previously used by Major Herschel. When Major Herschel and Captain Campbell were employed in latitude

work with the zenith sectors, they adopted the admirable system of giving full accounts of the whole procedure adopted each season, both in the observations and in the computations, pointing out any idiosyncracies that were remarked in the instruments and any peculiarities exhibited by the results. These summaries or, as they may be called, histories of the work are bound up with the computations of each season's work, and embracing, as they do, all the experiences obtained with these instruments, proved of great value to me, and must prove so to any one who has to use the sectors in the future. The same system of historical record has been adopted with regard to the longitude operations and the instruments employed in that work.

Before taking the field, the clocks, chronographs, and telescopes employed in the Longitude work were also set up and overhauled; transits were taken with both telescopes for a determination of the personal equation between Captain Campbell and myself, and some circumpolar stars were observed for the re-determination of the wire intervals of No. 1 telescope. A curious circumstance may here be mentioned with regard to the effect of a firm attachment on the rate of an astronomical clock. When clock No. 1134 was first set going, there were no convenient points in the room to attach it to, and it was set up with the base of the clock case merely resting on the floor which was firm and made of cement in the usual Indian fashion. It was found, on comparison with a chronometer, that when the bob of the pendulum was screwed up to its full extent the clock in this position lost at a uniform rate of 123 seconds a day. It was thought that this must be due to an escape of mercury from the cistern, but as no such escape had been detected, it was considered advisable, before proceeding to open out the mercury cistern, to have some firm supports arranged in a doorway, to which the clock case was screwed up in the usual manner. The clock when thus fixed, and with the bob screwed up to its full extent as before, was then found to gain 79 seconds a day, shewing a difference in rate of 3 minutes 22 seconds a day due to the change in the manner of supporting the clock case. It appears from this that the whole clock case, when not fixed, moved to a certain extent with each oscillation, thereby changing the position of the point of suspension of the pendulum and increasing the amplitude of the arc of vibration.

(2). The equipment of the party was sent off to Madras by goods' train on the 21st December, and I followed on the 26th, but the equipment did not arrive until the 30th. I had intended to leave Madras by a steamer due on the 2nd of January, but that steamer broke down and this circumstance, together with the irregularity of the steamer service caused by the immense rice trade that had sprung up to meet the scarcity prevailing in Madras, prevented me from leaving until the 10th of January. I arrived at Vizagapatam on the 13th and found that Mr. Bond had everything in readiness for me. From this station the two arcs, Vizagapatam—Madras, Vizagapatam—Bellary were to be measured.

(3). It was now the middle of January when fine weather might be expected, but the work was excessively delayed by abnormally cloudy weather, quite of a monsoon type. The first arc was not completed until the 1st of February, and when Captain Campbell had moved up to Bellary and was ready to commence the second arc, the weather had become so stormy that we were unable to do any satisfactory work until the 17th of February, eventually finishing this arc on the 25th.

Although, as a rule, cloudy nights entail on the observer almost as much sitting up as fine nights do, since there is always fair expectation of a break, yet on this occasion the clouds were so dense, heavy and continual, that on several nights no attempt was made to observe. A good deal of office work was in consequence got through during the day, the transcription of the chronograph sheets and the reductions of the first arc being well advanced before the observations for the second were commenced. At Captain Campbell's suggestion, a referring mark for the transit was built at Vizagapatam, nearly in the meridian, on a hill about four miles to the north of the station, so that in the event of failures to obtain circumpolar stars for azimuth, on nights when transit stars were observed, a value of azimuth might still be deduced for that date from micrometer intersections of the referring lamp, night by night. As it so happened, azimuth stars were obtained whenever they were required, yet the referring mark was a great source of comfort under cloudy skies, and in future whenever a convenient site can be obtained, a referring mark should be arranged for by the Assistant who prepares the longitude station, and in low latitude other advantages might well be sacrificed to obtain such a site.

(4). The party eventually left Vizagapatam for Mangalore on the 28th of February, and reached Madras on the 3rd of March. The instrument, and camp equipage were left on board the steamer to go round by sea, but the individuals of the party, both Native and European disembarked, and after six days sojourn in Madras crossed the peninsula by rail to Beypur, re-embarking there on board the same steamer on the 15th of March. This appeared to me, for many reasons, a far better arrangement than the alternative of sending the whole party round by sea. In the first place I was in daily anticipation of hearing that the Government of India had sanctioned a proposal for a determination of the difference of longitude between Bombay and Suez, in which case it was desirable that I should proceed at once to Bombay; in the second place an opportunity was thus offered and secured of doing six or seven days' good work in the reductions of the observations on shore, in place of practically nothing on boardship; and in the third place the Native Establishment was composed, with one exception, of Hindoos who eat nothing but raw or parched grain on boardship, and I did not feel justified in sending these men round by sea.

We did not arrive at Mangalore until the 18th March, where pillars for the instruments had been built a month previously by Mr. Neuville, a few yards south of the positions of the pillars employed in 1872-73.

(5). Regular work was commenced on the arc Mangolore—Bombay on the night of the 22nd. On the 23rd, I heard that sanction had been obtained for the determination of the difference of longitude between Bombay and Suez. The observing season was now far advanced, and to complete the connection of Bombay with Suez this season, it was essential that the observations in Bombay should be undertaken before the gathering of the monsoon clouds, to effect which it appeared necessary for me to start for Bombay by the next steamer. As the steamer was not likely to arrive until the 31st there would, under ordinary circumstances, have been ample time to complete the usual six nights' observations; but we were unfortunate in this respect. I was unable to work on the 23rd, owing to an inflamed eye. On the 27th the telegraph line was interrupted, and about noon on the 28th, I heard that the steamer would be in before her time early next morning, and I had a hard day's work to get everything down and packed up in time to start by her. The Arc Mangalore—Bombay is therefore dependent on only four nights' work, which however is probably sufficient to give a good result.

6). The party left Mangalore by sea on the 29th, and landed in Bombay on the morning of the 2nd of April. A fortnight was spent there with Captain Campbell in consulting and arranging a system for cable communication; in the determination of personal equation, and in various preliminaries connected with the novel work we were about to undertake.

The longitude station adopted at Bombay and used for the previous work on land lines was in the grounds of the Colaba Observatory, about three miles distant from the cable office. On land lines we had been able to work directly from station to station, but now that the signals had to be transmitted either to or from the cable office, this distance became a great disadvantage; it entailed the presence of an assistant at the cable office for the greater part of the night to look after the signals and prevented verbal communications in case difficulties arose, as was likely to happen with a new system on its trial. But there were so many objections to changing the station, that we had to do our best as it was, and the disadvantages, when the work once got into swing, were less than had been anticipated.

Captain Campbell was ready at Aden on the 24th of April, and on that night we had some preliminary practice, commencing regular work on the Arc Bombay—Aden on the 25th.

(7.) By the first system adopted for the interchange of signals, the clock at Colaba was placed in connexion with a relay at the cable office, which it worked by the usual break of contact at each second. During the times that signals were being exchanged between Bombay and Aden, the relay was placed in connexion with the electrified ink of the Thomson syphon recorder, so that, by a simple arrangement, whenever the relay broke contact, the electricity passed from the ink to earth, thus arresting the flow of ink through the syphon recorder and marking each second of the clock amongst the cable signals on the Tape. It was found however, after two nights trial that this system did not give satisfactory results, and on the 27th Captain Campbell telegraphed the details of a new system which proved a great success. This system, which I believe to be original, and for which Captain Campbell deserves much credit, consists in placing a relay in the circuit of the cable battery between the signalling key and the battery, so that whenever the key is pressed the current passes out through the cable as usual, merely weakened by the additional length of the relay coils, and at the same time works the relay. At Bombay this relay was in connection with one of the pen armatures of the chronograph at Colaba, so that each signal sent from Bombay to Aden was recorded on the chronograph at Colaba alongside the clock signals. Two days were spent in perfecting this system, after which our work proceeded very smoothly, so far as the comparisons were concerned, although retarded somewhat by cloudy nights at Aden, where they were least anticipated. The Arc Bombay Aden was completed on the 9th of May.

(8.) The party left Bombay by steamer on the 14th of May and arrived at Aden on the 21st. The Telegraph Office at Aden was, at this time, in course of removal from the house near the landing place, to the new block of building in Telegraph Bay, whence the cable signalling is conducted. Mr. Stacey, the Superintendent of the Telegraph Company, kindly placed at my disposal a row of thatched rooms which his staff had recently vacated and which enabled me and my assistants to live on the spot close to the longitude station and to the cable office.

The work at Aden proceeded perfectly smoothly and the arc Aden—Suez was completed on the 30th of May, and is the only Arc of the season where a succession of five clear nights were experienced simultaneously at both stations.

(9.) During the time I was observing at Aden, Mr. Connor carried a triangulation across the Peninsula to connect the longitude station with the Marshag light-house and with Lord Lindsay's station for the observation of the Transit of Venus. The triangulation started from a base line about $\frac{1}{4}$ of a mile long, measured twice over with a metallic tape which had been compared with a standard bar at Dehra. It was not originally intended to mark any but a few of the most important stations of this triangulation; but when Mr. Connor was selecting the stations, he found the hill tops to be in such a loose crumbling state as to require platforms to be constructed for the Theodolite, and, as a mason was required for this purpose, mark-stones with the usual circle and dot were placed at all the stations, except Lord Lindsay's. This station had previously been marked by a carronade sunk to ground level, but a mark-stone was in course of preparation, and the Assistant Resident informed me it would soon be placed on a pillar to be built over the station, which it so happens is just outside the building in which the pendulums were swung by me in 1873.

(10.) The interval of a week which elapsed between the completion of the longitude observations and the arrival of the next steamer was spent in overlooking this triangulation, in taking some latitude observations, reading off chronograph sheets and packing up. On the 7th of June the party embarked for Bombay on board the *Arcot*, in which Captain Campbell's party had left Suez, and the combined parties arrived in Bombay under my charge

on the 14th; the instruments and camp equipment were sent thence by goods' train to Poona, where office was opened and the recess season commenced on the 22nd of June.

(11.) The boxes containing the instrumental equipment have experienced some rather rough usage this season. Both at Vizagapatam and Aden everything had to be carried about by most unruly coolies, and at each place, up and down a steep hill where the coolies could not be well controlled; the equipment has twice passed in cargo-boats through heavy surf; twelve times it has been slung either to be shipped or unshipped; and although the boardship method of slinging is not quite so hazardous as it looks at first sight, yet it is not devoid of considerable danger to instruments, as was proved at Aden by a collimator box slipping out of the slings and rolling off the cargo-boat into the sea; the box, being a well-made English one, fortunately floated just long enough to enable it to be secured, without resorting to the amphibious Somali for its recovery, and the collimator inside the box sustained no damage beyond the wetting, which however was so thorough as to have partly corroded some of the smaller screws. Otherwise, although the boxes have suffered in their six months' travels, the instruments have remained in good order, the breakage of a glass cover of a hanging level being the only injury detected.

(12.) *Mr. C. J. Neuville* joined the party on the 7th of November 1876 in place of Mr. H. E. T. Keelan who had been transferred to the Mysore Survey. After being instructed in the forms of computations in use in the party, and being furnished with plans and memoranda, he left Bangalore on the 17th of December for Mangalore where he constructed the longitude station, and where it was intended he should remain until the arrival of this party. But in the *interim* his services were required by Captain Campbell at Madras, and so it arose that he joined and remained with Captain Campbell for the rest of the field season.

13. *Mr. E. T. Connor* joined the party in Bombay early in April. As he had not previously been employed in astronomical work, he required a good deal of coaching; but he mastered the work of recording and the preliminary computations rapidly, and soon become a useful assistant.

(14.) *Mr J. Bond.*—Mr. Bond was with this party during the whole field season. He left Bangalore on the 14th of December for Vizagapatam, and with good judgment he there secured, at a low rent, a house in the grounds of which he built the transit and collimator pillars in an excellent situation, about 100 yards from the trigonometrical hill station of Meppen, the clock pillar being erected in a room of the house where the clock was well protected from currents of air or sudden changes of temperature. He executed the triangulation necessary to connect the longitude station with the coast series, protected and transferred to the local officials two stations, acted as my recorder, and during the cloudy weather we experienced at Vizagapatam he made great advances in the computations. At Bombay he received some instruction in taking transits, so that, if the weather there proved as cloudy as was anticipated, he might take a few stars during some portion of the night; but the fine weather experienced rendered this unnecessary and his duties lay at the cable office where, at stated times, he sent signals simultaneously to Captain Campbell at Aden and to me at Colaba. At Aden he was similarly employed, but as the longitude station was close to the cable office there, he was able to act as my recorder in the intervals between the comparisons. Mr. Bond has performed his duties both in the field and during the recess in a very satisfactory manner. He has displayed good judgment, skill, and tact when he had to act independently, as for instance at Vizagapatam, where he chose the position of the longitude station, and at Bombay where he had control of the cable signalling during the time of the comparisons and he has worked well at the computations.

(15.) The native establishment consists, with one exception, of Hindoos from the North-Western Provinces and their custom of refusing to eat cooked food on boardship and subsisting only on dry and parched grain with a little *goor*, unfits them for long sea voyages, and on the way from Madras to Vizagapatam a duffadar who had but recently recovered from diarrhœa died in a few hours from an acute return of the disease brought on by this unwholesome diet. This was the only casualty during the season, and the health of the men has otherwise been very good; the sea voyages were cheerfully undertaken by them, and no objections were raised even to the long sea voyage over the *Kali pani* to Aden and back. I had expected difficulties at Aden with the natives about the condensed water; but when they found that it was drunk by other Hindoos and that the canal water was exceedingly brackish, they used it after a few grumbles.

(16.) I have to acknowledge much assistance, in the course of the season's work, from the several Telegraph officials with whom I came in contact. I am more particularly indebted to Mr. Flindell, the Superintendent of the Ganjam Division, who, when his office at Vizagapatam was short of signallers, and I was much troubled by induced currents, came up to the Observatory at night and spent some hours in signalling for me with his own hands. In Bombay, Mr. B. Smith, the Superintendent of the Eastern Telegraph Company, and his assistants gave us every facility for carrying on the work, in the first instance explaining the cable signalling instruments which were quite new to me, and subsequently, when difficulties arose, they were always ready to afford personal assistance, which must frequently have been rendered with great inconvenience to themselves. I have also to thank Major Gambier, R. E., the Superintendent of Military Works at Aden, and Mr. F. Chambers, who, in the absence of his brother on furlough, is in charge of the Colaba Observatory, for many little services rendered to me in connection with the work.

(17.) In conclusion, I may remark that I have purposely avoided going into details regarding the systems and methods followed in our operations, as Captain Campbell has, in his report, entered fully into these matters.

Extract from the Narrative Report, dated 19th October 1877, of Captain (now Major) W. M. Campbell, R.E., Officiating Deputy Superintendent, 2nd grade.

Employment.

1. During the past field season Captain Heaviside and myself have continued the determination of differential longitudes by means of the electric telegraph.

Operations of 1875-76.

2. At the date of my last report we were approaching the completion of the reductions of such observations made in season 1875-76, and I was enabled to submit the results in a postscript. Shortly afterwards however changes were found advisable in the method of reduction, which caused considerable re-computation, and altered the results, though only by small quantities. I now append the final results of 1875-76, and will revert to the cause of the alteration in a later part of this report (paragraph 41).

Programme for 1876-77.

3. By considerable exertion the reductions were completed by the end of the year, when we separated for our cold season's observations, the programme proposed for which was as follows:—The measurements of arcs Vizagapatam—Madras, Vizagapatam—Bellary, and Mangalore—Bombay. Besides these, the measurement between Bombay, Aden, and Suez by cable was contemplated, if the necessary sanction could be obtained. This measurement was urgently advocated by the Astronomer Royal, Sir George Airy, in order to complete the connection between Greenwich and Madras, the European section of which, between Greenwich and Suez, had already been executed on the occasion of the Transit of Venus in 1874.

Bombay—Suez Measurement.

Movements.

4. As the preliminary operation of the season, we determined our personal equation in December before leaving Bangalore. For the first measurement, Vizagapatam—Madras, Captain Heaviside went to Vizagapatam and I to Madras. I afterwards moved to Bellary while he remained at Vizagapatam, for the measurement Vizagapatam—Bellary, on completion of which we moved simultaneously to Bombay and Mangalore, respectively, for the measurement of that arc.

Progress impeded by weather.

5. The season proved particularly unfavourable for observation owing to clouds, which caused so much delay, that we did not begin observations between Bombay and Mangalore until 22nd March. Up to this date the question of carrying on the operations by cable to Aden and Suez was still undecided, but on 23rd March I heard from Colonel Walker by telegraph, that the sanction of Government had been obtained. The season was so far advanced that no time was to be lost, and we therefore curtailed our ordinary programme of measurement between Mangalore and Bombay by two days, in order that Captain Heaviside might not lose the first weekly steamer to Bombay, where he arrived on 1st April.

Bombay—Suez measurement sanctioned.

Preparations for cable work.

6. On 2nd April I despatched Mr. Neuville to Aden by P. & O. Steamer, to make all the preparations there. I had abundance of employment in Bombay in connection with the details of working by cable, both before and after Captain Heaviside arrived from Mangalore, and we finally settled on a method of working which promised to be exceedingly simple and efficacious. I shall revert in the proper place to this subject. We also observed on four nights for personal equation, after which I packed up my instruments and proceeded to Aden by the P. & O. Steamer of the 16th April.

Captain Campbell at Aden.

7. Arriving at Aden on 23rd, I found the preparations in a fairly forward state, and no time was lost in getting ready for observations. The observatory was conveniently situated about 150 yards from, and some 60 feet above, the new cable office, which had lately between completed. We began observations through the cable on 25th April, and worked (under great difficulties at Aden) on that night and the next on the system which we had fixed upon in Bombay. On the latter date I came to the conclusion that a change of method was absolutely necessary and hit on a happy alternative plan (described in paragraph 26 *seq.*), which we introduced on the 28th, after which we had no difficulty with the cable work.

Clouds at Aden.

The weather had caused us much anxiety, as the season was very late for star observations at Bombay; but fortunately Captain Heaviside enjoyed fine clear nights there, while at Aden, where we had reckoned pretty confidently on clear skies, I was troubled with frequent clouds lying low on the horizon, so as seriously to interfere with azimuth determinations, which are accordingly a weak point of the observations.

Captain Campbell proceeds to Suez, and Captain Heaviside to Aden.

8. We closed observations on 9th May, and I left Aden for Suez by P. & O. Steamer on the 14th. Mr. Neuville had preceded me by the mail of 30th April, and on reaching Suez on 20th May, I found the station building ready to receive the instruments, which were immediately put up. Captain Heaviside being also ready at Aden on 25th we began observations on that day, and continued nightly without interruption or difficulty until 30th,

when, having obtained six nights of good observations, we considered the measurement complete and closed work for the season.

Return of the parties to India.

9. I fortunately succeeded in despatching Mr. Neuville with the men and instruments per P. & O. Steamer of 1st June, which picked up Captain Heaviside's party at Aden on the 7th. Having been granted three months' privilege leave on completion of the field operations, I took advantage of it on 4th June. Captain Heaviside proceeded direct to Poona for recess quarters, where I joined him on the expiration of my leave on 30th August, since which date I have been steadily employed on the reductions. These are now in a forward state, and I hope to be able to give some results as a postscript to this report.

Captain Campbell takes privilege leave.

Measurements made by land wires.

10. With regard to the three measurements by land wires which we completed, I may remark that, although the distances were greater than we had formerly attempted, we found no difficulty whatever on that account. This applies particularly to the measurement Mangalore—Bombay, between which places the course of the wire is so circuitous that its length aggregates about 1,000 miles, and moreover the section near Mangalore is not so well insulated as is generally the case. We were led to expect great difficulty in exchanging signals direct between these two places, without intermediate relays, but with batteries of about 90 cells all anxiety on this head proved groundless. The three measurements obtained complete two more circuits, *viz.*, Vizagapatam—Madras—Bellary, and Madras—Mangalore—Bombay, the observations of 1872-73 between Madras—Mangalore being involved in the latter.

Circuits completed.

Method of working.

11. In these measurements we followed the methods employed during the preceding season, with but slight modifications and additions. The use of the telegraph wire was always obtained for the whole period of observations nightly, and the transits were observed at both stations with one clock, each being used alternately. Clock comparisons were only taken as a precaution, and have not been read off or used in the reductions except where occasionally necessary.

Precautions introduced.

Some extra precautions dictated by experience were observed in the commutator arrangements, with a view to eliminating as much as possible the effects of interference of currents, which it is impossible altogether to avoid.

Faults of apparatus.

The fact is that our magnetic recorders are not at all what they should be, because when I got them made up in 1875, I was obliged to use the materials available, *viz.*, the electro-magnets belonging to the original form of the apparatus. These were originally intended for use in connection with long lines as well as short local circuits, and they are not at all adapted for the latter, which is now the only way in which they are employed; the importance of this fact has grown upon us with experience. By a change in the connections of the pair of coils forming each magnet, which I introduced in Bombay in April, the total resistance was divided by four, and reduced thereby to an average of 170 units for all. This was found a great improvement, but it might be carried much farther, coils of about 30 units resistance being probably those best adapted for our purpose.

Partial correction.

Source of discrepancies found in results—
(1)—Astronomical.
(2)—Electrical.

12. With regard to the source of the discrepancies which sometimes occur in our results, some question has been raised as to the comparative responsibility of the astronomical and the electrical parts of the observations. I am afraid that the chief blame must be awarded to the former. The electrical part may be divided into two portions, *viz.*, as affected by (1) the arrangements inside our observatories, and (2) the line connecting the two stations. The previous remarks show that I do not consider the first of these as above suspicion, and that this part of our equipment is open to improvements, but I should rank the errors likely to arise on this account as quite secondary in importance to the astronomical errors. As to the second, the electrical behaviour of the line between the observatories, I do not for a moment believe that any appreciable error can be laid to its charge, provided there is direct communication without relays, as has always been the case in our operations. In this opinion I think I should be supported by that of all electricians.

Preliminary experiments for working by cable.

13. On receiving the order for observing between Bombay and Suez, I at once began the preliminary preparations and experiments, which were rendered necessary by the fact of cable work being quite novel to us.

Method of observing.

As regards the method of carrying out the observations, the use of the cable would compel us to abandon the system of using the same clock for transits at both stations, for two reasons—

(1). It seems impossible to transmit the beats of a clock through the cable, and record them on the distant chronograph; and (2), even if this could be done, the use of the cable could not be obtained for sufficiently long periods, for the night is the busiest part of the 24 hours on these cables. We were therefore obliged to have recourse to the method of comparing

clocks at fixed times, and observing transits with each clock locally before and after each set of comparisons.

Method of comparing clocks through cable considered.

14. My great object was to contrive a method of recording mechanically at both stations, signals sent alternately from each, so as to obtain a comparison of clocks free from any personal equation. So far as I am aware this had never previously been accomplished, a personal equation having always entered in the observation and record of the reflecting galvanometer, with which I believe all longitude observations by means of electric cables have hitherto been carried out. I hoped to effect my object by means of the Thomson Syphon Recorder, which was fortunately in use on the Bombay—Suez Cable. This is a beautiful instrument recently invented by Sir William Thomson, a few descriptive remarks on which will not here be out of place.

The syphon recorder.

15. A very fine syphon of glass is suspended in the most delicate manner, so as to be affected by the currents passing through the cable, which jerk it in opposite directions according as they are positive or negative. The upper end of the syphon dips into a reservoir of ink (aniline blue), and the lower end is very nearly in contact with the paper tape on which the record is to be produced, but the calibre of the syphon is so very fine that the ink must be forced through it, which is done in the following way :—

The "mouse-mill."

At the top of the instrument there is a wide wheel about 6 inches diameter and nearly the same width, technically called the "mouse-mill," which is driven by an electro-magnet below it. The motion of the "mouse-mill" serves two ends—(1) it draws the paper tape past the syphon, at a rate which can be regulated at pleasure with, as we found, great uniformity : (2) it induces a powerful current of statical electricity, which is conducted by a brass rod terminating in a point, towards a disc of brass, the distance of which from the point of the rod can be varied. This disc is in connection with the ink reservoir, and thus the ink becomes electrified to a degree which is regulated by the distance between the point of the rod and the disc. The insulation of the mouse-mill and the ink reservoir must be very perfect, as the static electricity, which is of high tension, will leak away through the slightest opening. The paper tape affords the nearest conductor for the escape of the electricity in the ink to earth, and this suffices to force the ink through the syphon and across the minute interval between it and the tape.

Electrification of ink.

Signals produced.

When no current is passing through the cable the syphon remains at rest, and traces a straight line along the centre of the tape, which is called the "Zero line." Positive and negative currents jerk the syphon aside in opposite directions, so as to mark signals on opposite sides of the Zero line. When working the cable on the 'simplex' method, all signals transmitted and received are recorded on the tape, the former being very sharply defined as compared with the latter; but when arranged for 'duplex' working, the signals transmitted are not locally recorded.

Necessity of signalling from Cable Office.

16. Our observatory at Bombay (Colaba) was about three miles from the Telegraph Office, and as all connections between land wires and cable are strongly objected to, on account of the risk of damage to the latter by lightning, it was necessary that the signals for comparison of clocks through the cable should be made in the Telegraph Office.

A method of comparing clocks described.

17. The first idea was that at each station the signals transmitted through the cable should be recorded on the local chronograph, as well as on the local and distant tapes—single signals being sent from each end alternately. This would afford a record of a series of received signals B, B, each occurring between two transmitted signals A, A, so that by measuring the intervals on the tape, and assuming uniformity of its motion, the former, B, B, may be interpolated in terms of the latter, A, A (see fig. 2, plate facing page). Now the signals A, A, B, B, being also recorded on the local chronographs their exact local times are known, and thus the difference between the clocks is arrived at by the observations at each station, only affected by retardation of signals, which enters with different signs at the two ends, and may therefore be considered as cancelled when a mean of both results is taken.

Objections and difficulties.

The only objection I saw to this method, besides the fact of the reductions being laborious, was being obliged to trust the rate of the tape; but experience has since proved that each series of signals (A, A, B, B) can be transmitted at intervals of less than three seconds, and that for such intervals the rate of the tape is quite sufficiently good. While considering the best method of arranging for the record on the chronograph of the signals transmitted through the cable, which presented some difficulties, another system occurred to me which promised many superior advantages.

A more promising method described.

18. It has been already remarked that great attention is requisite to keep the ink reservoir perfectly insulated, failing which the flow of ink is at once arrested. With reference to this it was pointed out to me as an interesting fact, that a touch of the finger, or even of a pencil, on the reservoir sufficed to stop the ink, and it immediately struck me that we might so connect our clock with

the reservoir as to put the ink to earth at each second, thereby marking the seconds on the tape by breaks in the ink line.

This was accomplished with some little trouble, in the following way:—A polarised relay was placed on the table beside the syphon recorder, and the signals from the clock passed through it, so as to work the armature at each beat. A fine wire was passed from the ink reservoir to the armature, so that at each beat connection with earth was obtained. This failed, because the insulation of the relay was not sufficiently good, and the mere contact with the table gave sufficient leakage to stop the ink altogether, independently of the position of the armature. A small contrivance fitted to the relay, however, effected our object, and we had the satisfaction of procuring a beautiful record of seconds on the tape by means of little breaks in the ink line.

Put in execution.

The record of a comparison of clocks then took this form. Hand signals by key were transmitted from each station in alternate series (instead of in series of alternate signals as above), and recorded on both cable tapes, while on each tape the seconds were marked by the local clock, and thus the local and distant times of each signal could be compared with great facility.

Exchange and record of signals.

19. The advantages of this system over the former were that—(1) The rate of the tape was only relied on for intervals of one second; (2) the results of comparison could be deduced with very much less labor; (3) a comparison could be carried on without in any way interfering with the work in the observatory, because the connection of the clock with the relay, &c., was under the control of the signaller in the Telegraph Office, who only required to note certain times on the tape by a clock or watch (which had been compared with that of the observatory), in order that the observatory clock's record on the tape might be properly identified as regards minutes. The beginning of each minute was, of course, marked on the cable tape, just as on the chronograph sheets, by the omission of one signal. These were all great advantages, and the last not the least so, as it permitted the observation of transits without interruption, and relieved the observer of all anxiety on account of the clock comparisons. The first of these methods may be known as comparison of clocks by "longitude signals," and the second by "ink-arrest signals," and if my description has been followed, it will be evident that nothing in the shape of a personal equation of observation enters into either, though it is possible that personal peculiarities of using the signalling key may produce minute variations in the retardation of the signals.

Advantages of second method.

Comparison of clocks named—
(1) by longitude signals,
(2) by ink-arrest signals.

20. The success of continued experiments with the "ink-arrest" method at Bombay was most satisfactory to both of us, and we agreed to adopt it for the observations. It need hardly be pointed out that this arrangement involves no connection between the land line and the cable, and therefore introduces no danger to the latter.

"Ink-arrest" method adopted.

21. It is well known that the retardation of a signal through a cable is very much greater than that of a signal transmitted by a land wire, and in the case of long cables it becomes a very considerable quantity. The lengths of the cables used by us are, between Bombay and Aden 2,172, and between Aden and Suez 1,864 miles. In such observations as ours, one must be content with assuming generally that the retardation affects signals equally in both directions, in which case its effect is perfectly eliminated by the method of working. Unpleasant suspicions, however, will occur that this may not be the case, and that the retardation may be affected by the direction of the signal relatively to the magnetic poles, or the rotatory motion of the earth, or by the direction of existing earth currents, or above all by the nature of the current used, whether by zinc or copper to earth at sending station.

Retardation of signals.

22. When Major Herschel and I began electro-longitude operations in India in 1872-73, we acted on these suspicions, and introduced regular changes of current during observations, with a view to cancel the effect of such variations, and even if possible to measure some of them. Later however I came to the conclusion that the retardation on land lines being so very minute a quantity, and its variations therefore presumably much more minute, it was vain to hope to detect these variations by means of observations affected by much more serious causes of errors. If our reports for season 1872-73 be referred to, it will be seen that different values of retardation according to direction and nature of current were assigned, but I added what appeared a probable reason why the apparent differences should be fictitious, and due to our apparatus, and further experience has only confirmed me in that opinion. Accordingly, as these changes of current, involving reversal of batteries, were troublesome, and complicated the work, Captain Heaviside and I abandoned them altogether for land-wire measurements.

Original precaution against variation.

Precautions abandoned on land lines.

23. In cable work however the question is very different; here the retardation itself is so much increased that we can no longer afford to neglect its possible irregularities, but must take advantage of every precaution promising to eliminate their effects, while we may hope with more reason even to detect and evaluate some of the variations. Moreover, the

Cable retardation a serious quantity.

existing arrangements in cable offices, facilitate changes of current, because instead of the dots and dashes of the Morse alphabet, jerks of the syphon to one side or other of the zero line are substituted, and these are produced by a double key the connections of which reverse the battery. It was therefore arranged that each comparison of clocks should consist of four sets of 16 signals in each direction, thus—

Precaution against variation.

Details of a comparison.

	Signals from E.	Signals from W.
1st set of signals, with currents.	+	+
2nd " "	—	—
3rd " "	+	—
4th " "	—	+

and we agreed to make three such comparisons nightly. This was afterwards reduced to two.

24. When I began observations at Aden I found it best to do the cable signalling myself, for although Mr. Neuville was available at first, there was the prospect of his leaving for Suez in the middle of the work. This happened to be practicable, because, as before noted, the observatory was within about 150 yards of the cable office, and the only objection was the loss of the third advantage claimed above (paragraph 19) for this system of comparison, *viz.*, the non-interruption of transit observations.

Bombay – Aden comparisons.

We had no means of testing the ink-arrest system completely until we actually attempted to carry it out ourselves between Bombay and Aden, when I saw immediately that it would be very difficult to work with. It has been already noted that great care is required to maintain the insulation of the ink; this was especially the case at Aden where the atmosphere was extremely damp, and I found that while the electric tension was sufficiently great to *maintain* the flow of ink, it often failed to *start* it again after interruption. The result was that great delay was experienced in getting the comparisons, interfering so seriously with my work in the observatory that, for that reason alone, I found it would be advisable to make a change if possible. Besides this, however, I was ashamed of the amount of time during which we occupied the cable, and feared an intimation that the interference with traffic was too great to be permitted. We had two nights of more or less unsuccessful struggling to obtain the comparisons at Aden, during which it generally took nearly 45 minutes to obtain any passable results, and I then began to despair of attaining anything like success with the ink-arrest process, while I did not see my way clearly to any satisfactory substitute.

Difficulties.

Weak point of the "ink-arrest" method.

That method condemned and a change considered.

25. In describing the method of comparison by longitude signals as being the first which was considered at Bombay, I mentioned that there was a difficulty in arranging for the simultaneous transmission of the signals through the cable, and to the local chronograph, and this was now the only thing that prevented my proposing the adoption of that system instead of the ink-arrest method.

Difficulty of arrangement.

As I was walking home on the second night, much disheartened and very tired (the work in the Aden climate being most harassing), the way to overcome this difficulty occurred to me, and next morning, having tested it successfully, I telegraphed to Captain Heaviside to adopt it. Fortunately the necessary alterations were very simple, and no difficulty was met with in carrying it out.

Difficulty overcome.

26. The new arrangement was as follows:—One of our ordinary polarised relays was introduced into the cable circuit between the signalling key and cable (at R), so that every signal transmitted by the cable passed through the coils and worked the armature of the relay. At first I thought that it would be necessary to reverse the connections of the relay so as to get the same armature action with both (±) currents, but it was pointed out from Bombay that, by placing the relay between the cable battery and earth (at R), the reversal of currents passed into the cable did not affect their passage through the relay. This is shown in diagram No. 1, (plate facing page) where both positions of the relay are given, the first being in dotted lines. The signalling key (K) is double, the members being so connected with the battery that the use of one puts zinc to earth and copper to cable, giving + current, while the other does the reverse, and gives — current. In the secondary circuit of the relay, *i. e.*, the circuit made and broken alternately by the armature action, one of the chronograph pen coils (C) was included, so that the action of the armature made a signal on the local chronograph, and thus every signal transmitted by the cable was also recorded on the chronograph. It took very little time to arrange this at both stations, and it proved quite successful, removing entirely any difficulty in making the comparisons, which were now carried out as follows:—

Details of new arrangement.

Put in execution.

Each comparison consists of four sets of signals, known as A, B, C, D exchanges, each of which should contain 32 individual signals, sent alternately from each station. Changes of current are introduced systematically:—

Details of a comparison.

thus, for A exchange, current from E +, from W +
B " " " E —, " W —
C " " " E +, " W —
D " " " E —, " W +

The whole operation only occupies about eight minutes from first to last.

27. The relay was placed closed alongside of the syphon recorder, and could be cut out of the cable circuit altogether by the transposition of a contact peg from P to Q. This was always done when the cable was used for talking purposes, but its omission in no way interfered with the cable work, so that there was no risk of the relay retarding the ordinary work of the office. In this case, as before, no connection was introduced between the cable and land wires, and it will also be noted that the relay could no longer in any way interfere with the action of the syphon recorder.

Ordinary cable work not interfered with.

28. The connections of the cable for receiving and sending signals require alteration, which is done by a switch alongside of the signalling key. For our comparisons, therefore, this switch had to be moved after receiving every signal, and again after sending the return, and this was the only part of the process which gave us any trouble at first. It also interferes with the record, because, on putting the switch over after transmitting a signal there always occurs what is known as a "kick" from the condensers, which are placed between the key and earth, causing a violent disturbance of the syphon. An exact copy of the record is attached (see diagram No. 2, plate facing page), on which the transmitted signals are marked A, A, and those received B, B, the unmarked digressions being the effects of the "kick." The kick can only be traced at the distant end by a slight displacement of the zero line.

Description of the signalling and of the record produced.

29. It would be a great advantage to avoid the use of the switch, both in order to get rid of the kick and for the convenience of the signaller; and it is possible to do so by adopting a modification of the 'duplex' system of working, in which the switch is not used. I have already mentioned that when working duplex the transmitted signals are not locally recorded, but this is only absolutely true when the electric balance (the secret of the duplex system) is perfect; and when that balance is thrown out, the transmitted signals are recorded in a degree depending on the amount of the disturbance. This exactly suited our purpose, because we could disturb the balance just sufficiently to obtain well-marked local signals. We tried this in the morning (when we could generally obtain the use of the cable for protracted experiments) with excellent results, and we agreed to introduce it for the comparisons the same night. We found, however, that it was not practicable for a continuance, because the cable being almost always worked on the simplex system alterations were required if we worked by duplex, which were not under our own control, and caused delay and trouble in the office. We had therefore to content ourselves with the less perfect record of comparison obtainable with the simplex arrangement.

Improvements possible by duplex arrangement.

Tried with success, but found impracticable.

30. I may remark here that our experiments in Bombay included many of which no notice has been taken, because it was found that the objects aimed at were impracticable for the above reason, *i. e.*, because of interference with the usual arrangements of the cable offices, which it is necessary to avoid as much as possible.

Interference with cable office arrangements to be avoided.

31. All the comparisons between Bombay and Aden were signalled by Mr. Bond at Bombay, and by me at Aden. At Suez, where the observatory was a mile from the cable office, Mr. Neuville did the signalling with Mr. Bond at Aden.

Execution of comparison.

32. In the reduction of these comparisons the interpolation of the received, between transmitted, signals seemed likely at first to prove very laborious, but as the work went on, the regularity of signalling became so great, that I found it quite feasible to use a glass scale of converging lines, such as we have always used for reading the chronographic records. With such a scale the interpolation becomes very simple, the interval of B after A being read off at once in decimal parts of the tape interval A A, and converted into seconds by multiplying by the known (chronographic) time interval A A. While in England I was able to have a set of these scales made, and they have proved of the greatest service.

Reduction of comparisons.

Glass scale for reading.

33. With regard to reading off the tape records of comparisons, the question arises as to the part of each signal which should be used, and the choice lies between two, *viz.*, the first departure of the syphon from the zero line, which we have designated the "initial disturbance," and its maximum divergence, which we call the "crest." The retardation of the latter is of course much greater than that of the former, but this affords no argument in favor of either, so long as the constancy of both retardations is considered equally good. *Ceteris paribus*, the variations of the greater quantity must be more serious than those of the smaller. There seems moreover good reason for suspecting more irregularity in the retardation of the "crests," as this must surely be more dependent on the manner in which the key is used, the force with which contact is made, and the interval of time during which it is maintained, as also on the state of the batteries and condensers.

Question as to the part of the cable signal to be used.

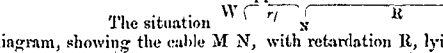
For the above reasons I would prefer using the "initial disturbance" of the received signals, but unfortunately these are not nearly so well defined as the crests, and a much greater uncer-

tainty of reading enters. We have therefore made a practice of reading off both, which will afford two complete sets of comparison results with different features, as to which I can only say at present, that the retardation by the crests will be about double that by the other set, while I expect the probable errors of crest results to be considerably the smaller. The exact method of combining the two remains to be decided.

34. The foregoing remarks apply only to the signals received through the cable (B, B,) on the tape record. Of the transmitted signals (A, A,) the first indication is always used, not only as more reliable in itself, but because it corresponds most nearly to the twin signal on the local chronograph. As a large personal equation may probably obtain in reading these tape records, its effect has been guarded against by my reading the whole set.

First indication of local tape signal adopted.

35. There is a feature in the retardation of signals involved in the clock comparisons as we carried them out, which calls for recognition, although it can have had no appreciable effect on our work of last season. The situation



is sketched in the diagram, showing the cable M N, with retardation R, lying between the two land wires connecting the cable office and the observatory at each end, the retardations of which are called $r\,r$. Now a signal made at M is recorded on the chronograph at E, and on the tape at N, after intervals r and R respectively, so that (R being always greater than r or r), the record at N is R—r later than that at E. Again the record at M is later than that at W by R—r. Thus it appears that we cannot use this method on the theory of equal retardation in both directions, unless we are justified in assuming $r=r_{,}$. As the distances between the office and our observatory were only about 3 miles at Bombay, 150 yards at Aden, and 1 mile at Suez, this assumption is safe.

Combination of land wire and cable retardation.

37. Some notice of the points chosen for our stations during the season will be given here. Those at Madras, Bellary, Bombay, and Mangalore were the old points formerly used as longitude stations, the method of fixing which, by connection with stations of the Trigonometrical Survey, has been already described.

Station sites, and how fixed.

At Vizagapatam a convenient site was chosen, and connected with the Trigonometrical Survey by minor triangulation with a 12-inch theodolite. At Aden Captain Heaviside observed the latitude of the station with a 10-inch theodolite, and connected the station by a small survey, for which a base line was measured, with several points of importance on the island, including the old pendulum station, and Lord Lindsay's station for his chronometrical determinations of longitude for the Transit of Venus. It was an object at Suez to adopt the same point as that used for the observation of the Transit of Venus, when the observatory was placed on the mound of earth some 40 feet high, on which the building known as the Khedive's Chalet stands. We had no precise data for the discovery of this station, but I am glad to say that Mr. Neuville hit on the exact spot, which I fixed by measurement as being 91 feet 9 inches from the south-east corner of the Chalet, and 49 feet 3 inches from a flag-staff on the mound. I afterwards found that Mr. Hunter, who was in command of the Transit of Venus party, gave these same measurements for his station as 91 feet 8 inches and 48 feet 6 inches. It was this point which had already been connected longitudinally with Greenwich.

Aden.

Lord Lindsay's longitude station connected.

Transit of Venus station at Suez.

38. There was another station used at Suez by Lord Lindsay's Transit of Venus party, for the purpose of a determination of differential longitude with Aden, where the station adopted has been already alluded to. The point at Suez was close to the cable office, and was connected with our station by means of a traverse carried out with theodolite and tape.

Lord Lindsay's longitude station at Suez connected.

39. Our station at Suez had one objection, arising from the fact of the mound having originally been artificial, though I believe of somewhat ancient date, in consequence of which the foundation of the piers was faulty. This showed itself distinctly in the levelling, which proved that settlement was going on from day to day throughout the observations, and I am sorry to say that the azimuth observations show the same, which affords reason to fear that our results may have somewhat suffered from this cause.

Bad foundation at Suez.

40. Having now given a narrative of the season's work, and endeavoured to explain whatever of novelty has entered into the operations, on account of their extension by sub-marine cables, I shall turn to a few points of interest in the observations generally.

Narrative of the season completed.

41. At the beginning of this report, I alluded to a change in the mode of reducing the observations of 1875-76, which was rendered necessary by the discovery of an interesting feature in our personal equation of star transits.

Reductions of 1875-76.

When our reductions were approaching completion last year I received a pamphlet, from the United States Hydrographic Office, on electro-longitude operations and personal equation, in which reference was made to a machine for measuring personal equations. This directed my attention to a method for measuring absolute personal equation by means of the

Machine for measuring personal equation.

chronograph, which I had myself devised some years previously, but for various reasons had never carried out practically; and certainly it could not have been relied upon to give results for comparison with the equations obtaining in star observations, because of the difference of the conditions. This contrivance (somewhat modified on account of the alterations since made in our apparatus) Captain Heaviside and I now proceed to use, with the following interesting result, *viz.*, that we found our relative equations to vary according as we observed an object travelling from right to left, or from left to right.

Difference in equation according to direction of motion of object observed.

Now, as we take all our transits in a sitting posture by means of an oblique eye-piece, it follows that stars north and south of the zenith cross the wires from right to left, and left to right respectively, and therefore, according to the discovery just made, the observations of such stars should be combined with different personal equations.

42. A re-discussion of all divided transits, taken for relative personal equation throughout the season, was then gone through with the stars divided into two groups north and south of the zenith, and the result strikingly confirmed that indicated by the absolute equations. The original equation for all stars having been $C - H = +\ 0^s{\cdot}064 \pm 0^s{\cdot}0057$, we now found—

New reduction of personal equation for the season 1875-76.

By north zenith stars $C - H = +\ 0^s{\cdot}102 \pm 0^s{\cdot}0087$.
And by south zenith stars $C - H = +\ 0^s{\cdot}041 \pm 0^s{\cdot}0034$.

The portion of the reductions combining the star observations by both of us was then re-computed with the two new equations instead of the old one, and it is very satisfactory to note that a marked improvement in the general accordance of the final results was obtained. In carrying this out some difficulties arose from the fact, that when a star is very close to the zenith it may be equally conveniently observed either as a north or south star, whence in many cases it was doubtful how an observation should be treated.

Re-computation, with improvement in results.

43. We have fully recognized this feature of personal equation during last season's work now under reduction, carefully noting at the time on which aspect a zenith star was observed. We also, when possible, adopted a mean zenith for the two ends of an arc,—say in declination 15°15′ for Madras and Vizagapatam, in latitude 13°, and 17°30′ respectively—so that, the southern observer treating all stars south of this mean zenith as south stars, while he at the north station treated all these north of it as north stars, all transits were taken with the same aspect at both stations. Besides this, each observer made a practice of taking several stars close to his own zenith on both aspects, *i. e.*, he observed them over the first ten wires as north stars, and then turning round took the last ten wires as for a south star, *or vice versâ*, and in this way each has obtained a good value of his absolute equation between north and south stars for each station. This we call the "N—S" equation.

Precautions introduced in season 1876-77.

Each observer's absolute equation of north and south stars, known as the *N*—*S* equation.

41. The results for our combined observations for relative personal equation by divided transits (as before) which were carried out on 15th, 18th and 19th December, and on 4th, 5th, 7th, and 9th April, with both instruments, are also carefully grouped for stars of north or south aspect, giving a relative equation for each. These we call "$C_n - H_n$", "$C_s - H_s$" respectively. As we cannot make choice of one of these as of more value than the other, the method in which we propose treating the whole subject is this.

Relative personal equations by north and south stars known as $C_n - H_n$ and $C_s - H_s$.

All the results of each observer will be treated as obtained from north stars, by applying his absolute N—S equation to his south stars, and these will be combined by means of the relative equation $C_n - H_n$ obtained from north stars. Again, all individual results will be reduced to south stars and combined by the south star equation $C_s - H_s$, and finally a mean of the two results will be taken.

Application.

It may be as well to note that this N—S equation is attributed wholly to the fact of the stars crossing the field in opposite directions. Difference in the rate of motion has very likely a secondary effect, but on that point I can produce no evidence.

45. Our personal equation determination of this season is not quite so satisfactory as that for 1875-76, as in the first place we had not so many opportunities of carrying it out, and in the second the results obtained are not so accordant. After all, however, the whole thing cannot rank much above a rough approximation when carried over such long periods, with so many changes of condition affecting the observers. For instance, it is easy to suppose that a week of seasickness will seriously affect an observer's personal equation. This must always remain the weak point of observations for differences of Longitude.

Uncertainty of personal equation.

46. Besides the personal equation of transits, there is the probable equation in reading off the chronograph sheets to be guarded against. Last year this was done by taking care that the same person should read the records at both stations of any particular piece of work, but that could not be arranged this season, because each observer was able to transcribe a large part of his own

Personal equation of reading records.

records in the field. This equation has therefore been determined by comparing transcripts of the same record by both observers. It amounts to about 0·01.

Azimuth observations.

47. The determination of the azimuthal deviations of the transit instruments has given more trouble than usual during last season's observations, on account of the prevalence of clouds.

Distant referring lamp at Vizagapatam.

To supplement star observations, Captain Heaviside introduced at Vizagapatam a distant referring lamp, about 4 miles from the Observatory, and I strongly recommend the use of such a lamp whenever practicable, which however is not often the case.

Not practicable at Aden.

At Aden, where I had great difficulty in obtaining observations of either circumpolar or comparative azimuth stars (see last report, Art. 24), I put in practice a contrivance which had occurred to me for using a referring lamp at a comparatively short distance. About 500 yards was the utmost available at Aden, and at this distance a mark viewed through a powerful telescope has so much parallax as to be quite unfit for observation.

Contrivance for using a near referring lamp.

48. I had a tin cap made with a small opening of about $\frac{1}{8}$ inch diameter, and when this was affixed in front of the object glass, a very good image of the referring lamp became visible on the plane of the wires, and therefore without parallax.

The explanation of this is as follows. If a small portion only of a lens of long focus be used, the convergence of rays is so slight, that there is a considerable range on either side of the true focus, within which a fairly distinct image will be formed on a screen. In the present case the screen is imaginary, but its position is defined by the focus of the eye-piece, which is, of course, adjusted to be coincident with the plane of the wires.

The relative positions of the referring lamp and telescope being constant, the position of the image of the former, seen on the wires of the latter, will vary according to the position of the small opening in the tin cap with reference to the object glass, as is shewn in diagram No. 3, (plate facing page.)

Here O O is the plane of the object glass and F F that of the wires, *i. e.*, of solar focus; and f is the focus of the near referring lamp. A B C D and a b c d are, respectively, transverse sections of the object glass in the plane O O, and of the cone of rays, of which the object glass is the base and f the apex, in the plane F F.

Now, if the referring lamp be observed through the small opening placed at A, B, C, or D (the telescope remaining fixed), its image will be seen at a, b, c, or d respectively; and the closer the referring lamp is to the telescope, the greater will be the distances of a, b, c, or d apart.

Method of observing it.

49. The collimator being directly in the line between the telescope and referring lamp, in order to observe the latter (without moving the collimator or seeing through it), it was necessary to place the small opening opposite the extreme edge of the object glass, as at D, and thus the referring lamp was observed as at d, although really placed on the prolongation of the axis of collimation R f.

This is a matter of no consequence, so long as the tin cap is always put on in exactly the same position, because the referring lamp readings are only treated differentially from night to night. Thus, if an absolute value of deviation is obtained from star observations on any one night, and compared with a reading of the referring lamp on that night, then by comparing the latter with referring lamp readings on any other night, a value of deviation can be deduced. If it is required to combine readings of the referring lamp taken with telescope I. P. E. with another set taken I. P. W., care must be taken when reversing the telescope to obtain the following observations: (1) a reading of the referring lamp with the opening in its old position; (2) a reading of the collimator with the whole object glass before reversal: again, after reversal, (3) a reading of the collimator with whole object glass; and (4) a reading of the referring lamp with the opening in its new position.

The readings of the collimator (2) and (3) show any change of azimuth which may have occurred in the process of reversal, and this, combined with the difference between the readings (1) and (4), gives the quantity, which must be applied to a set of readings taken after reversal, in order to make them comparable with those taken before. The difference of the collimated readings of the telescope micrometer in the two positions I. P. E., I. P. W., must not be lost sight of in carrying out this process. It may be added, that the observation of azimuth being in view, A, C (or top and bottom) are the worst parts of the object glass to use, while B, D (at the sides) are the best, because errors of position (of the tin cap) in these parts give respectively maxima and minima horizontal displacements in the image observed.

Nature of stars observed.
Longitude stars only for Indian arcs.

50. On the land lines measured, we made use, as before, of longitude stars only, *i. e.*, stars selected without any exact knowledge of their right ascensions and observed at both stations.

For the Aden—Bombay measurement this system was not wholly convenient on account of the great difference in longitude, because it is, of course, advisable that the clock comparisons should be taken as nearly as may be at the mean time of star observations, which is impossible when the western observer has to wait two hours for the set of stars taken by his colleague at the east station. We, therefore, adopted a combination of longitude stars and clock stars, according to which each observer determined his own clock error by well-known stars, while a small group of longitude stars was also taken by both. Between Aden and Suez the difference of time is only 49 minutes, but here, on the other hand, there is nearly 20° difference of latitude, so that the same set of stars would have a very northerly average position at Aden and the reverse at Suez, which is objectionable on account of deviation errors. For this reason it was considered best to confine ourselves to clock stars.

Combination of clock and longitude stars for Bombay—Aden.

Clock stars only for Aden—Suez.

51. Between Bombay and Aden we only used the new cable for clock comparisons, because a fault which at that time existed in the older cable made it difficult to work through, and unsuitable for our purpose. Between Aden and Suez we used the two cables nearly equally.

Which cable used.

Personal acknowledgments.

55. Mr. Pogson, Government Astronomer at Madras, gave me, as usual, every facility for carrying out my work at his Observatory.

Mr. Pogson.

Mr. F. Chambers.

Mr. F. Chambers, who was acting for his brother, Mr. C. Chambers, in charge of the Observatory at Colaba, was also most obliging and anxious to meet my wishes on all points.

56. I have, as usual, to acknowledge the greatest courtesy in meeting our wants from all the officers of the Telegraph Department concerned. In the matter of electro-longitude work, the Great Trigonometrical Survey owes much gratitude to the members of the sister department, from their late lamented chief, Colonel Robinson, R. E., downwards, for hearty co-operation and assistance.

Officers of the Indian Telegraph Department.

57. When we began the cable operations, the Directors of the Eastern Telegraph Company were good enough to allow us the free use of the lines for our observations, and also gave instructions that we should be allowed every facility, provided the traffic were not impeded. These instructions were most liberally interpreted, and the amount of work which we were allowed to do with the cables often surprised me. The fact of the duplication of the cable having just been completed between Suez and Bombay was, of course, a great advantage to us in this respect. We met with the greatest attention in all the offices, *viz.*, at Bombay, Aden and Suez; everything was done to assist us, and much interest seemed to be taken in our progress. To Messrs. Smith, Stacey and Tuck, Superintendents at Bombay, Aden and Suez, respectively, our thanks are particularly due, most especially to the first-named, in whose office the preliminary experiments were carried out, and the delays at first starting experienced.

Officials of the Eastern Telegraph Company.

58. I am also very grateful to Dr. Muirhead, who was in Bombay when we first entered on the work, in which he took a lively interest, and was always ready with advice or assistance in making experiments. Dr. Muirhead was not officially connected with the cable, but being the inventor of the artificial cable—a set of condensers ranged on shelves in the office, so constructed as to give an exact imitation of the real cable as regards resistance, leakage, &c., by which the balance is obtained for duplex working—he came to Bombay to see it brought into use with the new Bombay—Suez cable, the laying of which was only completed last March.

Dr. Muirhead.

59. The British Consul at Suez, Mr. West, was very obliging, and assisted us in many ways, particularly in getting us permission to use the site we desired, and to build upon it; in procuring workmen, and also in passing our instruments through the Custom-house without delay.

Mr. West, H. B. M. Consul at Suez.

60. When in England on privilege leave I took the opportunity of visiting Greenwich, in order to describe what we had done to Sir George Airy. I took with me specimens of the chronographic and cable tape records, and explained our system of comparing clocks. Sir George showed the greatest interest in the matter, and was good enough to express great admiration of our records.

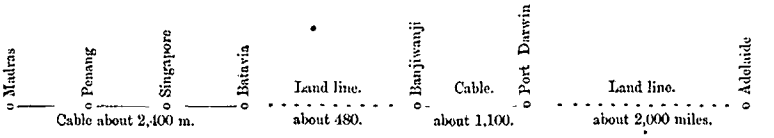
Visit to Sir George Airy at Greenwich.

61. I then ventured to express my opinion of the desirability of extending these operations, by which India is now connected with Greenwich, to the Australian colonies, a question into which the Astronomer Royal warmly entered, and at his request I afterwards furnished sketch estimates of the expense which would be incurred if such operations were at any time carried out.

Question of Australasian longitudes.

I eventually pointed out that, by the system which we had adopted, extended as described in paragraph 35 of this report, but somewhat modified and complicated because the syphon

recorder would not be available, it might be hoped to connect Madras and Adelaide with only one astronomical station between, as shewn in the diagram—



Direct signalling would probably be practicable through the cables joined up between Madras and Batavia, so that the measurement might be made in one operation with astronomical stations at the two ends. Then the section Batavia to Adelaide might be measured with only signallers at the ends of the intermediate cable (as described in paragraph 35).

It is true that the land wire of about 2,000 miles across Australia might be a formidable section to work through, though, considering the dryness of the climate, I have but little doubt that it would be practicable. This point, however, does not affect the question, as it may be taken for granted that no Astronomer will ever visit the centre of Australia (in our time at least), in order to provide an intermediate station of observation on the telegraph line, and if the distance should prove too great for direct signalling, the work will be done, if ever, by means of introducing relays. This could be carried out just as well on the system now under discussion as with an astronomical station at Port Darwin, only one would advocate the precaution of introducing, between Banjiwanji and Batavia, as many relays as might be used in crossing Australia, in order to obtain nearly equal retardations on these two land lines.

Extract from Supplementary Narrative Report, dated 16th January 1878, of Captain (now Major) W. M. Campbell, R.E.

Since writing my Narrative Report, the reductions of last season's work have been completed and the results arrived at, which I have now the pleasure of submitting, and I shall take the opportunity of making a few additional remarks which have suggested themselves during the progress of the computations.

Clock comparison by cable.

As regards clock comparisons and the transcript of two sets of signals, *viz.*, those afforded by the "initial disturbance" of the syphon, and by the "crests" of the waves, the results have borne out the expectations expressed in the body of my report. The crests give results with smaller probable errors, but their value of retardation, while about twice as great as that by initials, is also not nearly so constant.

Wave or syphon time.

A feature has been found which was not thought of at the beginning of the work, *viz.*, a constant difference between the two ends of the cable, in the interval of time between initial and maximum (or crest) disturbance.

This we have called the "wave or syphon time," the alternative designation being employed because of the doubt existing as to the exact nature of the interval, which seems to arise from a combination of two causes—

Causes.

(1).—A cable requires time to take up its maximum charge, which may be called the "wave time;" and this time is dependent not only on the state of the cable, but on that of the batteries and condensers, and on the mode of using the key.

(2).—According to the adjustment of the syphon, the same current from the cable will produce a greater or less disturbance, and the interval between initial and crest effects on this account is called "syphon time." This interval will depend on the state of the batteries of the electro-magnet, of the syphon-recorder, and on the suspension of the syphon itself.

Effects.

It need hardly be remarked that the different values of this interval at the two stations is an important matter. If it arises wholly from wave time, the initials of signals are probably least, if at all, affected, and would therefore give the best results. If, on the other hand, it were due to the syphon time only, it might be considered that the syphon making the greater excursions would start sooner, and continue the movement later, *i.e.*, that the initial movement of the one would be nearly as much before that of the other, as the crest would be later; and in this case the mean of the two would probably give a result nearly cleared of the effects of the difference.

Treatments of results.

I am not prepared to advance a decided opinion on the best treatment. I believe that the wave time is the more probable source of the difference, and that, therefore, the initial results are to be preferred. I held this opinion from the beginning, but the idea of syphon time did not occur till later, and it now seems to me that it is probably to a certain extent responsible, particularly as a slight inspection of the record shows a marked relation between the difference in the heights of the waves and the difference of the wave or syphon time, at the two stations. On the other

hand, there is the fact, that when the cable was changed in the measurement Aden—Suez, the sign of the wave time difference was reversed, although the same recorders were used as before.

The difference of clocks has been taken out in two ways—(1) by using the initial signals only, and (2) by taking a mean between the initial and crest results.

The difference of longitude has, however, been deduced only from the "initial disturbances." This is somewhat arbitrary, and it would be satisfactory to obtain an opinion as to the best treatment, by an electrician who should have access to the results of all battery and cable tests, taken while our work was in progress.

Such an opinion, so far as I have been able to get it, *viz.*, from Mr. Smith, Superintendent of the Eastern Telegraph Company in Bombay, who, however, was not so thoroughly acquainted with the facts as desirable, is in favor of the course adopted.

In the present case it is after all more a matter of curiosity than importance, the quantities being small, and their signs such that they nearly cancel in the whole measurement Bombay—Suez.

Recommendation for guidance in future.

I should certainly not recommend both initials and crests being read in future, but initials only, while a few crests might also be read in order to compare the wave times. Improvements in signalling would probably make the initials as good as the crests for reading, and the saving in time would be great, as the transcription of these tapes is very laborious.

Results obtained.

Results of the season's work.

Of the three land measurements executed, two, *viz.*, Vizagapatam—Madras, and Vizagapatam—Bellary, combined with Madras—Bellary, measured in 1875-76, complete a circuit, the closing error of which is $0^s{\cdot}041 \pm 0^s{\cdot}018$. This is disappointing, inasmuch as it is considerably greater than any similar error of the work done in 1875-76, but I cannot consider it surprisingly large. Unfavourable weather may have something to say to it, cloudiness being certainly likely to interfere with even the observations obtained. For a plausible explanation, however, we need not look farther than the uncertainties found to exist in our personal equation, as the difference between its values by the determinations preceding and following these measurements amounted to $0^s{\cdot}053$ and $0^s{\cdot}045$ for $C_N - H_N$ and $C_S - H_S$ respectively.

It is true that the equation affected both these arcs with the same sign, but the question is one of constancy, and the uncertainty seems quite sufficient to account for discrepancies of $0^s{\cdot}02$ or $0^s{\cdot}03$. Indeed, it may probably be assumed that any agreement within $0^s{\cdot}03$ is more or less fortuitous.

The arc Mangalore—Bombay, combined with Madras—Bombay, measured in 1875-76, and Madras—Mangalore of 1872-73, affords another circuit, the closing error of which amounts to no less than $0^s{\cdot}354$, the measurement of 1872-73 being in defect.

This is contrary to my expectations, as I hoped to find a close agreement, proving that the effect of the faults of No. 2 telescope during 1872-73 had been nearly eliminated in the whole measurement. I can only regret now that I was rash enough to make any prediction regarding the results obtained from that telescope in the condition it was in at the time.

Final longitude of Madras.

The longitude of the Madras Observatory, which results from combining our measurements between Madras and Suez, with the longitude of Suez supplied by Sir G. Airy, is $5^h\ 20^m\ 59^s{\cdot}416$, being $2^s{\cdot}116$ in excess of the value hitherto adopted, as given in the Nautical Almanac.

The effect of the season's operations is therefore to remove India, theoretically, about 2,000 feet farther from England!

Tables of results.

Tables of our results, with explanations, are appended to this report.

In these are included the elements of certain points fixed by triangulation at Aden, the data of origin being our longitude determination of this year, and the latitude observed by Captain Heaviside.

The position (by our traverse) of the point at Suez used for determinations of longitude, in connection with Lord Lindsay's transit of Venus Expedition of 1874, is also given.

Personal equation the limit to accuracy.

The uncertainties of personal equation must, I fear, always remain the great bar to obtaining in longitude observations, a degree of accuracy which will compare favourably with that arrived at in the best determinations of latitude, but there is room for improvement, and I hope the next series of observations entered upon will find us better armed against this our worst enemy.

Determination open to improvement.

Mathematical Instrument Department.

There has always been a weak point in the difference of power used with the two telescopes, owing to that of one eye-piece being about double that of the other. We have done what we could to obviate this by determining personal equation equally with both instruments, but this could, of course, only be looked on as a rough remedy. A new eye-piece has now been made in the Mathematical Instrument Department, Calcutta, of the same power as the best of the original pair, and this should bring the circumstances of personal equation, as determined, much more in accord

with those exsting during actual observations, and it may be hoped will effect a corresponding improvement in results.

Another minor point has been attended to by the addition of a few ordinary spectacle lenses, sliding loosely in a cap to be put on the eye-piece, so as to allow of the same focus of the eye-piece being used for two different sighted observers when taking divided transits, one observing with the spectacle lens and the other without. The focus of the eye-piece cannot be changed while taking such observations, and we have hitherto only been able to work in that way because the observers happened to have nearly the same eye-sight.

The great desideratum, however, is some contrivance for measuring absolute personal equation satisfactorily.

I have designed a simple instrument for this purpose, which I hope will answer the chief objects in view, *viz.*, to afford a close imitation of a real star transit, and to be easily brought into use during any available interval of a few minutes' duration. A detailed description cannot be given here; suffice it to say, that an imitation star will automatically record on the chronograph its transit across a series of wires, while the observer records the same events in the usual way.

This instrument is now being constructed in the Mathematical Instrument Department, Calcutta, and I propose calling it an "idiometer," for which name I am indebted to Major Herschel, R.E.

Abstract of Final Results of 1875-76.

CIRCUIT I.

			m s ″
ΔL	Bolarum—Bombay ...	... ...	22:48·849±·0059
„	Bellary—Bombay ..	... ...	16:26·959±·0114
„	Bolarum—Bellary ...	Deduced	6:21·890±·0128
		Observed	6:21·883±·0121
	Difference	... ...	0·007±·0176

CIRCUIT II.

			m s ″
ΔL	Madras—Bolarum ...	.. ..	6:54·692±·0109
„	Madras—Bellary ..	... ...	13:16·563±·0112
„	Bolarum—Bellary .	Deduced	6:21·871±·0156
		Observed	6:21·883±·0121
	Difference	... ...	0·012±·0198

CIRCUITS I AND II COMBINED.

			m s ″
ΔL	Bolarum—Bombay .	... .	22:48·849±·0059
„	Madras—Bolarum ..	... .	6:54·692±·0109
„	(1) Madras—Bombay ..	... ...	29:43·541±·0124
„	Bellary—Bombay ...	... ...	16:26·959±·0114
„	Madras—Bellary ..	... ...	13:16·563±·0112
„	(2) Madras—Bombay . .	... .	29:43·522±·0160
	Difference between (1) and (2)	... ...	0·019±·0202
	Mean of (1) and (2)	... ...	29:43·534±·0101

CIRCUIT III, 1872-73 and 1875-76.

			m s ″
ΔL	Madras—Bellary .	... ...	13:16·563±·0112
„	Bangalore—Bellary	... ...	2:37·364±·0126
„	Madras—Bangalore deduced	... ...	10:39·199±·0169
„	Do. measured in 1873	... ...	10:39·043±·0102
	Difference	... ...	0·156±·0197

Explanation of terms used in accompanying statements.

$C_N - C_S$: $H_S - H_S$, respectively, indicate Captain Campbell's and Captain Heaviside's absolute equations between the observations of stars of north and south aspect, (see report, para. 43).

$C_N - H_N$: $C_S - H_S$, are similarly the relative equations for combining the observations by both officers of north and south aspect stars (para. 44).

ΔL is generally, "difference of longitude."

ΔL_N : ΔL_S, are values of ΔL deduced from observations of all stars ; where observation of stars of south aspect are reduced to north aspect, by the equations $C_N - C_S$ $H_N - H_S$, for ΔL_N, and *vice versâ* for ΔL_S (see report, para. 44).

$C_r - H_r$, is the transcribing equation (para. 46).

ρ is the retardation of signals between stations on land lines.

Deduction of final values of Captains Campbell and Heaviside's relative personal equations, $C_N - H_N$, & $C_S - H_S$.

By Stars of North Aspect.						By Stars of South Aspect.		
Date.	Telescope.	Mean Value $C_N - H_N$ (a)	Weight (w)	(a)×(w)		Mean value $C_S - H_S$ (a)	Weight (w)	(a)×(w)
1876.		s				s		
December 15th ...	No. 1	+0·14	38	4·712		+0·057	48	2·736
„ 18th ...	Ditto.	·125	56	7·000		·069	38	2·622
„ 19th ...	No. 2	·150	64	9·600		·071	28	1·988
General Mean $= \frac{\Sigma a}{\Sigma w} \frac{b}{w} =$		s +0·135						s +0·061
1877.								
April 4th	No. 2	+0·085	9	+0·765		—0·028	23	—0·644
„ 5th	Ditto	·025	93	2·139		·004	222	·888
„ 7th	No. 1	·052	65	3·380		·025	35	·875
„ 9th	Ditto	— ·027	23	—0·621		·042	303	12·726
General Mean $= \frac{\Sigma a}{\Sigma w} \frac{b}{w} =$		s + 0·030						s —0·026

Final values adopted.

For land measurements, carried out between December 1876 and April 1877, means of the above are adopted, *viz.* :—

$$C_N - H_N = + \overset{s}{0}{\cdot}083, \quad C_S - H_S = + \overset{s}{0}{\cdot}019.$$

For cable measurements, executed subsequent to April 9th, 1877, the last determined values are adopted, *viz.* :—

$$C_N - H_N = + \overset{s}{0}{\cdot}030, \quad C_S - H_S = - \overset{s}{0}{\cdot}026.$$

The values of each observer's N—S equation are as below :—

for are	Vizagapatam	—Madras	$H_N - H_S =$	$+ \overset{s}{0}{\cdot}015$,	$C_N - C_S =$	$+ \overset{s}{0}{\cdot}077$.
„	„	—Bellary	„	+ 0·033,	„	+ 0·055.
„	Mangalore	—Bombay	„	+ 0·026,	„	+ 0·046.
„	Bombay	—Aden	„	+ 0·006,	„	+ 0·074.
„	Aden	—Suez	„	+ 0·022,	„	+ 0·058.

Abstract of resulting values of difference of longitude, Season 1876-77.

Details for land wire measurements.	Vizagapatam—Madras.	Vizagapatam—Bellary.	Mangalore—Bombay.
By E. Clock.			
$\Delta L_N - \rho$	m s 12: 9·853	m s 25: 26·410	m s 8 : 7·395
$\Delta L_S - \rho$	9·791	26·388	7·375
By W. Clock.			
$\Delta L_N + \rho$	12: 9·902	25: 26·491	8: 7·464
$\Delta L_S + \rho$	9·840	26·469	7·444
Whence ΔL_N	12: 9·878	25: 26·451	8 : 7·430
$C_N - H_N$	— ·083	— ·083	—·083
ΔL	12:9·795	25: 26·368	8: 7·347
Again, ΔL_S	12: 9·815	25: 26·428	8: 7·409
$C_S - H_S$	— ·019	— ·019	—·019
ΔL	12: 9·796	25: 26·409	8: 7·390
Mean ΔL	12: 9·796	25: 26·389	8: 7·369
$C_\tau - H_\tau$	— ·011	·000	·000
Final ΔL	12: 9·785 ±0·012	25: 26·389 ± 0·008	8: 7·369 ±0·013
Also ρ	+0·0250	+0·0405	+0·0345
Length of wire used	500 miles.	897 miles.	950 miles.

Details for cable measurements.	Bombay—Aden.		Aden—Suez.	
	1 h —51m		0h —49m	
By clock stars	s ΔL_N=19·972	s ΔL_S=19·904	s ΔL_N=42·661	s ΔL_S=42·625
$C_N - H_N$, or $C_S - H_S$ ...	—·030	+·026	—·030	+·026
$C_\tau - H_\tau$	+·011	+·011	·000	·000
Corrected resulting values ...	ΔL=19·953	ΔL=19·941	ΔL =42·631	ΔL =42·651
Mean ...	ΔL=19·947+0·026		ΔL=42·641±0·015	
By longitude stars	ΔL =20·021	ΔL =19·953	ΔL =42·707	ΔL =42·671
$C_N - H_N$, or $C_S - H_S$	—·030	+·026	—·030	+·026
$C_\tau - H_\tau$	+·011	+·011	·000	·000
Corrected resulting values ...	ΔL_n=20·002	ΔL_s=19·990	ΔL_N=42·677	ΔL_S=42·697
Mean ...	ΔL=19·996±0·016		Δ L=42·687±0·022	
Final value of ΔL	s m s s 1 : 51 : 19·983±·015		h m s s 0 : 49 : 42·656±·013	

Abstract of Results, 1876-77.

△L Vizagapatam—Madras	... ...	12: 9·785±0·012
„ Vizagapatam—Bellary	... ...	25:26·389±0·008
„ Madras—Bellary	Deduced ...	13:16·604±0·014
	Observed 1875-76 ...	13:16·563±0·011
	Difference ...	0·041±0·018
△L Mangalore—Bombay	.. ...	8: 7·369±0·013
„ Madras—Bombay, observed 1875-76	...	29:43·534±0·010
„ Madras—Mangalore	Deduced ...	21:36·165±0·016
	Observed 1872-73 ...	21:35·811±0·014
	Difference ...	0·354±0·021

Results of Seasons 1875-76 and 1876-77, combined to afford final value of △L Madras—Bombay.

The diagram shows the measured arcs available for the deduction, and the quantities are as below.

A	Measured in 1875-76	=	16:26·959±0·011
	C=22:48·849±·006		
	D= 6:21·883±·012		
A	=(C—D) deduced „	=	16:26·966±0·013
B	Measured	=	13:16·563±0·011
	E= 6:54·692±·011		
	D= 6:21·883±·012		
B	=(E+D) deduced „	=	13: 16·575±0·016
	F=25:26·389+·008		
	G=12: 9·785±·012		
B	=(F—G) deduced 1876-7	=	13: 16·604±0·014

Whence, using combination weights.

△L Madras—Bellary, Mean A = 16:26·962±0·009

△L Bellary—Bombay „ B = 13:16·578±0·008

△L Madras—Bombay, A + B = 29:43·540±0·012

The measurement D enters twice in the above deduction, which therefore is not quite rigorous.

Resulting value of the longitude of Madras.

	h.	m.	s.	
Longitude of Mokattam, East of Greenwich	2	5	6·320	Supplied by Sir G. Airy.
,, ,, Suez, ,, ,, Mokattam	0	5	6·917	
,, ,, Aden ,, ,, Suez	0	49	42·656	G. T. Survey, 1876-77.
,, ,, Bombay ,, ,, Aden	1	51	19·983	
,, ,, Madras ,, ,, Bombay	0	29	43·540	G. T. Survey, 1876-76-77.
Longitude of Madras east of Greenwich	5	20	59·416	

The longitude of Madras as given in the Nautical Almanac = 5 h. 20 m. 57·3 s.

Aden Triangulation.

	Latitude.	Longitude.
Elements of the Points.		
Longitude station	12° 46′ 27″·00	44° 58′ 38″·40
Lord Lindsay's station*	12 47 14·70	44 59 11·56
Intersected Points.		
Sham Sham flagstaff	12 46 30·30	45 0 41·88
Residency ,, ...	12 46 45·11	44 58 29·16
Saluting Pier ,, ...	12 47 20·88	44 59 58·49
Light-ship (outer)	12 47 20·45	44 58 18·52
Light-house (Marshag)	12 45 43·02	45 3 19·74
Renny's flagstaff	12 47 3·53	44 58 42·69

* The outer wall of the room in which the pendulums were swung by Captain Heaviside in 1873, is 86 feet distant from this station, in a direction 27° 30′ west of south.

At Suez.

The pillars used for the longitude observations in connection with Lord Lindsay's Transit of Venus expedition of 1874, were found by traverse to be 0·025 s. west and 23″ south of our longitude station. Whence their—

Longitude = 2 h. 10 m. 13·212 s., and latitude (approximate) 29° 57′ 56″.

At Colaba, Bombay.

The transit instrument of the Colaba Observatory was found by measurement to be 0·134 s. to the west of our longitude station. Whence—

Longitude of Colaba Observatory transit instrument = 4 h. 51 m. 15·742 s. east of Greenwich.

Mean result's regarding the retardation of signals through the cables.

The quantities tabulated are halves of the double retardations to and fro deduced from the clock comparisons.	Part of signal observed.	RETARDATION ACCORDING TO CURRENT AT EACH EAST OR WEST STATION.							
		E. +	W. +	E. −	W. −	E. +	W. −	E. −	W. +
BOMBAY ADEN									
(New cable) length 2172 miles	Initial ...	s. 0·285		s. 0·273		s. 0·282		s. 0·286	
	Crest ..	0·533		0·482		0·505		0·549	
ADEN—SUEZ									
Old cable, 1685 miles	Initial ...	0·306		0·294		0·299		0·286	
	Crest ...	0·557		0·533		0·547		0·541	
New cable, 1683 miles	Initial ...	0·266		0·270		0·277		0·258	
	Crest ...	0·517		0·499		0·499		0·516	

Wave or syphon times.

Area and cables	VALUES AT East.	VALUES AT West.	Difference E.—W.	Limits between which the differences vary.		N. of values of each sign. +	N. of values of each sign. −
BOMBAY—ADEN							
New cable	s. 0·256	s. 0·209	s. +0·047	s. +·185	s. −·036	53	15
Old cable	0·230	0·266	−0·036	−·235	+·008	1	27
ADEN—SUEZ							
New cable	0·240	0·241	−0·001	−·051	+·093	10	10

Extract from the Narrative Report, dated 16th January 1878, of J. B. N. Hennessey, Esq., M.A., in charge Computing Office.

On Mr. Cole's departure on furlough, 21st March 1876, the Calculating and Printing branches of the Computing Office were placed under Major Herschel, and the Drawing and Photozincographing branches under Captain Thuillier. This arrangement continued in effect until the return from furlough of Colonel Walker. Shortly after, I was directed to resume charge of the Office in all its four branches: Captain Thuillier then reverted to other duties; but Major Herschel continued to render aid in the supervision of the Calculating and Printing branches until the reduction of the North-East Quadrilateral was completed.

Calculating branch.

6. The following cost-table of work done in the Calculating branch is similar to the one exhibited last year; it differs from its predecessor in that, the number of classes of work has been reduced, by suitable grouping of the former classes, from 15 to 10:—

Cost-table in Rupees.

CLASSES.	November.	December.	January.	February.	March.	April.	May.	June	July.	August.	September.	Average per cent.
1. Records, Library ...	19	24	192	214	132	209	104	89	115	66	68	5
2. Computations ...	439	514	505	464	284	213	389	426	528	259	246	18
3. Accounts, returns, correspondence ...	151	132	161	280	206	342	265	304	312	517	299	13
4. Supply	107	68	68	66	75	67	51	30	58	63	57	3
5. Press copy	434	323	199	170	138	283	419	532	323	315	449	16
6. Press proofs ...	348	263	168	355	109	290	409	402	465	458	467	17
7. Charts	159	129	33	10	115	63	27	9	0	0	51	2½
8. Stations	178	58	57	121	61	35	71	41	80	18	69	3½
9. Leave, Holiday ...	146	558	670	323	419	370	150	45	39	132	202	13
10. Meteorology, Miscellaneous	146	58	74	124	288	255	242	239	197	269	225	9
TOTALS ...	2,127	2,127	2,127	2,127	2,127	2,127	2,127	2,127	2,127	2,127	2,127	100

DIAGRAM TO ILLUSTRATE REPORT ON LONGITUDE OPERATIONS.

by Major W.M. Campbell, R.E.,

7. The following particulars are due to the classes named in the foregoing:—

Calculating branch. Particulars of work.

(1). *Records, library.*—The crowded state of the rooms available compelled the adoption of contrivances for affording all practicable relief. Every year brings a sensible accession to our field records, as each executive officer makes his annual deposit; to this, add the considerable quantity of printed matter, amounting, in the 11 months under review, to no less than 3,35,000 prints, and some idea will be formed of the space required for stowing away the documents, so that they shall be safe and accessible. The simultaneous reduction of the North-West and South-East Quadrilaterals afforded an opportunity for packing away their original records; this has been done in convenient racks, after suitable paging, indexing, &c.; and it is further intended to roughly bind these papers in course of time.

8. *Clause 2.*—Computations—

N. E. Q.—Reduction taken up at elimination from 39th equation, and concluded.
S. E. Q.—Reduction of South Pársnáth and South Malúncha Series begun and concluded.
N. W. Q.—Reduction of Jodhpur Series carried as far as computation of co-efficients of the errors Y, Z.
S. W. Q.—Data collected (in part) for investigation of final weights.

Principal Triangulation in general (in duplicate).

Weights, computed	7
Spherical excesses, computed	42
Reduction of simple figures, computed or corrected	6
„ of compound „ „	5
Triangles, computed or corrected	1,464
„ arbitrary corrections applied in	100
Latitudes, longitudes and azimuths, computed (single deductions)	164
„ „ „ „ (2nd deductions)	624
„ „ „ corrected „	71
„ „ „ computed (3rd deductions)	84
Heights, corrected and adjusted	73
Azimuths (astronomical), computed	3
„ „ partly computed	32
Non-circuit azimuths, computed or examined	1,912
Auxiliary figures, computed	64

Secondary triangulation in general (in duplicate).

Traverses, computed	1
Triangles, computed and adjusted	126
Latitudes, longitudes and azimuths, computed or corrected	179
Heights, corrected	108

9. *Class 3.*—Accounts, returns, correspondence, as usual.

10. *Class 4.*—Supply. Data in manuscript has been supplied to 21 officers; and about 680 despatches of maps, charts, forms, and books have been made.

11. *Class 5.*—Press copy.

N. W. Q.—Re-transcribed, revised and compared degree lists 29 to 40 of North-West Himalaya series; and prepared a general alphabetical list of names of all the stations and points fixed on this series.

S. E. Q.—Azimuthal observations completed. Some re-transcription and a good deal of re-comparison found necessary in the matter set up for the synoptical volumes. Differences of height and height above mean sea-level revised for the East Coast Series.

N. E. Q.—Orthography of principal stations examined and revised; alphabetical and numerical lists prepared for the Assam, East Calcutta, Brahmaputra and Eastern Frontier Series. Descriptions prepared for the Budhon, Rangír, Karára, East Calcutta, Brahmaputra and Eastern Frontier Series. Reduction of figures, principal triangles, and synopses of latitudes, longitudes and azimuths prepared for the entire quadrilateral; and differences of height about half-ready. Abstract of angles prepared for the Budhon, Rangír, Assam and Brahmaputra Series; and the table of "sums of squares" prepared for the Assam, East Calcutta, Brahmaputra and Eastern Frontier Series.

S. W. Q.—Alphabetical and numerical lists prepared, and descriptions of stations partly prepared for all the series of this quadrilateral; also abstract of angles prepared for the Bombay Longitudinal Series.

Southern Trigon.—Abstract of angles prepared for the South Konkan, Mangalore, and Madras Meridional and Longitudinal Series (needs comparison to a large extent).

Miscellaneous.—Central Provinces, Hyderabad and Bombay, authorized lists of spellings of proper names re-arranged alphabetically for office use. Copy of spirit levelled heights, No. 2 Southern India, examined prior to sending to press. Introduction to volume of the Great Arc Series, Section 18° to 24°, and Appendix No. 7 to Volume II of the Account of the Operations, &c., prepared.

12. *Class 6.—Press proofs.* These are not susceptible of explanatory remarks. An estimate of the labour involved is supplied by the fact that 17 per cent. of the entire working power of the Calculating branch was necessarily absorbed by this subject.

13 *Class 7.*—Charts.

	NAME.	Completed or revised letter press.	Examined or compared.
		Pages.	Sheets.
Preliminary.	Madras Coast and Ceylon Connection, Season 1875-76	5	1
	Jodhpur Series, Season 1875-76	3	1
	Jeysulmere and Balmer Minor Series, Season 1875-76	5	1
	Eastern Frontier Series, Season 1875-76	7	1 in part.
	Thayetmyo, Prome and Myanoung Triangulation, Season 1875-76 ...	9	1
	Pegu, Rangoon and Coast Triangulation, Season 1875-76 ...	6	1
	Assam Valley Triangulation, Season 1875-76	.....	1 in part.
	Charts of Spirit Levelling Operations, Nos. 13, 19, 26, 39 ...	32	.....
	Index Chart of S. W. Q. Triangulation	.....	1
	Chart shewing all the principal stations in Hyderabad	.....	1
	Chart to illustrate Spirit Levelled Heights, No. 2 Southern India ...	.....	2
Final.	N. W. Himalaya Series, Degree Sheets Nos. 22 to 40	.....	11
	Reduction Chart, S. E. Quadrilateral	.....	1
	Great Arc Series, Section 18 °to 24°, No. 2	.....	1
	Bilaspur Series, No. 1	.....	1

14. *Class 8.—Stations.* Ten duplicate lists added, making a total of 323 settled districts accounting for 3,010 principal stations, and leaving about 20 districts yet to be settled. Four new lists accounting for 14 stations, and 42 duplicate or supplementary lists descriptive of 292 stations supplied (several in duplicate) to district officials.

TYPOGRAPHIC BRANCH.

16. The work annually performed or proportionally deduced may be briefly stated thus where the unit of a page is as heretofore taken at a certain standard size to make the total numbers comparable.

	1872-73.	1873-74.	1874-75.	1875-76.	1876-77
Pages composed ...	1,420	1,220	*1,319	*1,179	*1,535
„ printed ...	273,157	388,420	*372,647	*349,000	*495,573

The total pages composed during the eleven months under review may be sub-divided thus—

For volumes of the Great Trigonometrical Survey	1,098
„ Charts, memos., &c.	200
„ Annual Report	88
„ Pamphlet of spirit-levelled heights	21
Total ...	1,407

The large increase in the out-turn of printed pages is partly due to fortuitous circumstances.

PHOTOGRAPHIC BRANCH.

17. The following are details of the work executed by this Branch.

Maps.

SUBJECT.	When published.	No. of parts.	No. of copies printed.
Prints of maps published in former years	...	46	1,437
Goalpara Forest Map ... } For Forest Department ... {	October 1876 ...	1	645
Palamau „ „ ... }	„ „ ...	1	521
Ranikhet Map, Skeleton, *reduced*	„ „ ...	1	69
Guzerat Survey, Sheet No. 14, Section 16	„ „ ...	1	112
Dehra Dún and Siwálik Survey, Sheet No. XVI } For Forest De- {	November „ ...	1	142
„ „ „ „ „ „ XVII } partment ... {	„ „ ...	1	149
Index to Dehra Dún and Siwálik Survey	„ „ ...	1	424
„ Jaunsar Survey	„ „ ...	1	428
Spirit Levelling Operations, *No.* 42	„ „ ...	1	115
Ranikhet Map, Contoured, *reduced*	„ „ ...	1	87
Index to Guzerat Survey	December „ ...	1	436
„ to Triangulation by the Great Trigonometrical Survey of India. For Officiating Superintendent's Administration Report, 1875-76	„ „ ...	1	444
„ to main lines of levels (reduced scale)	„ „ ...	1	423
Route Map. For Captain Biddulph	„ „ ...	1	139
Byragarh Forest Map. For Forest Department ... —	„ „ ...	1	100
Kumaun and Garhwál, Sheet No. 20, Skeleton	„ „ ...	1	158
Dehra Dún and Siwálik Survey, Sheet No. XVIII ... } For Forest {	January 1877 ...	1	116
„ „ „ „ „ XXVI ... } Department {	„ „ ...	1	140
„ „ „ „ „ XXVII ... }	„ „ ...	1	145

* Average for a twelve-month.

...s—continued.

SUBJECT.	When published.	No. of parts.	No. of copies printed.
Spirit Leveling Operations, No. 19	January 1877 ...	1	110
" " " " 25	" " ...	1	109
" " " " 41	" " ..	1	107
Index to Kattywar Survey	" " ...	1	400
Hyderabad Territory, Skeleton Map, showing Sub-divisions and Great Trigonometrical Survey Principal Stations	" " ...	1	95
Index to Triangulation, S. W. Quadrilateral	February " ...	1	29
Dehra Dún and Siwálik Survey, Sheet No. XLI. For Forest Department	" " ...	1	133
Kumaun and Garhwál, Sheet No. 21, Contoured	" " ...	1	108
Guzerat Survey, Sheet No. 81, Section 7	March " ...	1	106
" " " " 14, " 13	" " ..	1	119
" " " " 14, " 15	" " ...	1	107
Kattywar Survey, Sheet No. 36	" " ...	1	135
Dehra Dún and Siwálik Survey, Sheet No. XXXV. For Forest Department	April " ...	1	140
Guzerat Survey, Sheet No. 81, Section 15	" " ...	1	107
Kattywar Survey, Sheet No. 45	" " ...	1	134
Dehra Dún and Siwálik Survey, Sheet No. XXV	" "	1	142
Kumaun and Garhwál, Sheet No. 19, Skeleton	" " ...	1	105
Mussoorie and Landour Survey, Sheet No. 13, Skeleton, 2nd Edition	" " ...	1	35
" " " " " Contoured "	" " ...	1	37
Kattywar Survey, Sheet No. 10a	May " ...	1	136
Kumaun and Garhwal, Sheet No. 11, Skeleton	" " ...	1	165
" " " " 24, "	" " ...	1	166
" " " " 30, "	" " ...	1	163
" " " " 7, "	" " ...	1	170
Guzerat Survey, Sheet No. 81, Section 8	" " ...	1	88
Kattywar Survey, Sheet No. 37	June " ...	1	133
Guzerat Survey, Sheet No. 82, Section 2	" " ...	1	85
" " " " 82, " 5	" " ...	1	87
" " " " 81, " 16	" " ...	1	87
" " " " 81, " 14	" " ...	1	85
Spirit Leveling Operations, No. 39	" " ...	1	119
Guzerat Survey, Sheet No. 81, Section 13	July " ...	1	87
" " " " 82, " 4	" " .	1	90
" " " " 14, " 14	" " ...	1	85
Spirit Leveling Operations, No. 26	" " ...	1	111
Guzerat Survey, Sheet No. 80, Section 16	August " ...	1	89
" " " " 82, " 1	" " ...	1	87
" " " " 82, " 3	" " ...	1	86
" " " " 14, " 2	" " ...	1	87
Kattywar Survey, Sheet No. 38	" " ...	1	136
Route Map, illustrating the Mullah's explorations in 1876 ...	" " ...	1	505
Dehra Dún and Siwálik Survey, Sheet No. XXX	" " ...	1	134
Spirit Leveling Operations, No. 13	September " ...	1	110
Mussoorie and Landour, Sheet No. 19, Skeleton, 2nd Edition ...	" " ...	1	35
" " " " 19, Contoured " ...	" " ...	1	35
" " " " 14, " " ...	" " ...	1	40
" " " " 15, " " ...	" " ...	1	37
Dehra Dún and Siwálik Survey, Sheet No. XXII	" " ...	1	143
Guzerat Survey, Sheet No. 14, Section 4	" " ...	1	87
" " " " 14, " 6	" " ...	1	92
" " " " 14, " 7	" " ...	1	88
Kattywar Survey, Sheet No. 60	" " ...	1	123
	Totals ...	117	12,348

Besides the foregoing, 108 blue-prints were issued, and 189 sets of silver prints (59 subjects) were prepared for the use of the engravers and for Executive Officers.

Charts.

SUBJECT.	When published.	No. of parts.	No. of copies printed.
North-West Himalaya Series, Degree Sheet No. 7, final ...	October 1876 ..	1	390
" " " " " " 14—15, " ...	" " ...	1	375
" " " " " " 5—6, " ...	November " ...	1	435
" " " " " " 12, " ...	" " ...	1	352
" " " " " " 13, " ...	December " ...	1	355
" " " " " " 10—11, " ...	" " ...	1	371
" " " " " " 8—9, " ...	January 1877 ...	1	377
" " " " " " 18, " ...	" " ...	1	425
" " " " " " 16—17, " ...	" " ...	1	431
" " " " " " 19, " ...	February " ...	1	376
" " " " " " 20, " ...	" " ...	1	367
" " " " " " 21, " ...	" " ...	1	374
Jodhpur Series, Season 1875-76, Numerical	" " ...	1	67

Charts—continued.

SUBJECT.	When published.	No. of parts.	No. of copies printed.
North-West Himalaya Series, Degree Sheet No. 22—23, Final ...	March 1877 ...	1	366
" " " " " " 24, " ...	" " ...	1	375
" " " " " " 25, " ...	" " ...	1	373
" " " " " " 26—27, " ...	" " ...	1	425
Madras Coast and Ceylon Connection Series, Season 1875-76, Numerical	" " ...	1	66
Joyaulmero and Balmer Series (Secondary), Season 1875-76, Numerical	" " ...	1	67
North-West Himalaya Series, Degree Sheet No. 37, Final ...	April " ...	1	402
" " " " " " 31—35, " ...	May " ...	1	377
" " " " " " 36—38, " ...	" " ...	1	315
" " " " " " 30 -34, " ...	" " ...	1	367
" " " " " " 39—40, " ...	June " ...	1	356
" " " " " " 32—33, " ...	" " ...	1	382
" " " " " " 28—29, " ...	" " ...	1	380
Eastern Frontier Series, Season 1875-76, Numerical...	" " ...	1	65
Thayetmyo and Prome Triangulation (Secondary), Season 1875-76, Numerical	" " ...	1	80
Pegu, Rangoon, and Coast Triangulation (Secondary), Season 1875-76, Numerical	August " ...	1	70
Assam Valley Triangulation, 1875-76, Numerical	" " ...	1	65
	Totals ...	30	9,225

Diagrams.

SUBJECT.	When published.	No. of copies printed.
Polygons and other figures to illustrate figural reductions for Vols. of the Great Trigonometrical Survey, Bench Marks, &c.	October 1876 ...	483
	November " ...	466
	December " ...	300
	January 1877 ...	433
	February " ...	255
	July " ...	1,928
	August " ...	91
	Total ...	3,956
Professional and Office Forms	1876-77 ...	21,384

Contrasting the work performed since 1872-73, we have—

YEAR.	Maps.	Blue-prints.	Silver prints.	Charts.	Diagrams.	Forms.
1872-73	6,910	Not reckoned.	Not reckoned.	2,206	12,055	12,549
1873-74	9,207	53	...	2,027	3,557	28,125
1874-75	7,040*	20*	...	3,015*	3,701*	24,219*
1875-76	14,025	12	126	1,678	9,722	18,314
1876-77	12,348	108	189	9,225	3,956	21,384

An abstract of the work executed during the past five years stands thus,—

SUBJECT.	NUMBER OF PRINTS.				
	1872-73.	1873-74.	1874-75.	1875-76.	1876-77.
Maps, Charts, and Diagrams	21,171	14,791	13,756*	25,425	25,529
Blue-prints and Silver-prints	Not reckoned.	Not reckoned.	20*	138	297
Forms	12,549	28,125	24,219*	18,314	21,384

The increase in the number of prints of Charts in 1876-77 is due chiefly to the copies required for illustrating our synoptical volumes; the increase of maps in 1875-76-77 arises from a corresponding increase in the number of originals presented for photozincography.

*Averages for a twelve month.

Drawing Branch.

(18). The principal work performed in this branch during the 12 months ended 30th September 1877 is detailed in the following table :—

DESCRIPTION OF WORK.	NUMBER OF SHEETS OR DIAGRAMS. Finished.	In hand.	Scale 1 inch =	REMARKS
COMPILATION.			Miles.	
Map to illustrate explorations made in connection with the operations of the Great Trigonometrical Survey of India in 1876 by "The Mullah," with hill shading.	1	...	8	For Photozinc: Reduction to ¾ scale.
Map to illustrate Captain Biddulph's route from Bunji *vid* Gilgit towards the Karambar Pass and to Hunza, with hill shading.	1		8	Ditto.
Chart to illustrate the Electro-Telegraphic determinations of differences of Longitude.	1	...	96	Ditto.
Index to main lines of levels by the Great Trigonometrical Survey, 2nd Edition, with corrections and additions to 1876.	1	..	40	Ditto. Reduction to ¼ scale.
Map of Trans-North-Western Frontier Region ...	...	1	4	Ditto.
Rough Chart of the South-West Quadrilateral Triangulation.	1	..	24	Ditto.
Chart illustrating the "Reduction of the South-West Quadrilateral."	1	...	12	Ditto. Reduction to ½ scale.
Sketch Map of the Hyderabad Territory, shewing sub-divisions and positions of principal stations of the Great Trigonometrical Survey.	1	...	16	Ditto.
Chart No. 1, illustrating Spirit Leveling Operations of the Great Trigonometrical Survey in 1873-74.	1	...	10	Ditto Reduction to ½ scale.
Chart No. 2, illustrating Spirit Leveling Operations of the Great Trigonometrical Survey in 1874-75.	1	...	12	Ditto ditto ¼ scale.
Sheet No. 13 of Spirit Leveled Heights ...	1	..	2	Ditto.
Do. „ 19 do. do.	1	..	2	Ditto.
Do. „ 26 do. do.	1	..	2	Ditto.
Do. „ 39 do. do.	1	...	2	Ditto.
Do. „ 53 do. do.	...	1	2	Ditto.
Do. „ 59 do. do.	...	1	2	Ditto.
Do. „ 2 Dehra Dún and Siwáliks ...	..	1	1	Ditto.
Do. „ 24 do. do. survey ...	1	...	½	Ditto.
Do „ 32 do. do. do. ...	1	...	½	Ditto.
Do. „ 40 do. do. do. ...	1	...	½	Ditto.
FINAL CHARTS.				
Great Arc Series, Section 18° to 24° (Secondary Triangulation.)	2	..	4	Ditto Reduction to ¼ scale.
Biláspur Meridional Series	2		4	Ditto ditto.
Calcutta Longitudinal Series	...	3	4	Ditto *ditto.*
Jubbulpore Meridional Series	...	2	4	Ditto ditto.
Bider Longitudinal Series	...	2	4	Ditto ditto.
PRELIMINARY NUMERICAL CHARTS.				
Jeysulmere and Balmer Minor Series, Season 1875-76	1	...	4	Ditto.
Secondary Triangulation—Pegu, Rangoon, and Coast, Season 1875-76.	1	..	4	Ditto.
Secondary Triangulation—Thayetmyo *vid* Prome and Myanaung towards Bassein and Cape Negrais, Season 1875-76.	1	...	4	Ditto.
MISCELLANEOUS.				
Examined and reported on 55 fair original maps of Kumaun and Garhwál, Kattywar, Guzerat, and Dehra Dhún and Siwáliks Surveys				
Examined 118 proofs of Maps and Charts ...				
Colored 6,313 Maps				

Taking Stock.

(19). In addition to the foregoing duties, stock was taken in all the four branches, as usual shortly after 1st January, of all records, books and stores belonging to the office.

Meteorological results

(20). Tables of monthly meteorological results are herewith appended as usual.

Monthly meteorological results taken from the Register kept at the Office of the Superintendent, Great Trigonometrical Survey of India, Dehra Dún.

YEAR AND MONTH.	BAROMETER. H. M. At 9-30 A. M. Highest.	Lowest.	Monthly mean.	BAROMETER. H. M. At 3-30 P. M. Highest.	Lowest.	Monthly mean.	HYGROMETER. H. M. At 9-30 A. M. Monthly mean Temperature of Dew point.	Monthly mean Humidity.	HYGROMETER. H. M. At 3-30 P. M. Monthly mean Temperature of Dew point.	Monthly mean Humidity.	THERMOMETER. Dry Bulb. Maximum in Sun's rays.	Minimum on grass.	Maximum in air.	Minimum in air.	Monthly mean in air.	Wet Bulb. Maximum wet.	Minimum wet.	Monthly mean wet.	RAIN. No. of days it fell.	Fall in inches.	WIND. Most frequent direction.	CLOUD. H. M. At 9-30 A. M.	H. M. At 3-30 P. M.
1876.																							
November ...	27·874	27·650	27·766	27·797	27·555	27·687	51·7	·662	52·5	·505	88·6	39·0	79·2	43·0	62·8	66·0	32·0	51·1	...	...	N. & W.	1	2
December ...	·951	·729	·844	·838	·641	·758	46·8	·675	47·4	·490	81·7	37·0	71·2	41·4	56·8	61·1	28·8	45·9	...	.	N.W.&S.	1	2
1877.																							
January ...	·973	·708	·861	·901	·629	·775	47·1	·790	47·2	·564	81·5	34·4	71·8	31·9	55·6	59·3	36·4	48·5	8	3·09	W. & S.	4	5
February ...	·890	·497	·775	·824	·431	·704	45·9	·785	46·8	·539	88·6	30·0	76·5	35·2	54·1	62·1	33·8	46·9	8	4·41	W. & S.	3	4
March ...	·820	·604	·709	·736	·525	·630	52·6	·668	52·4	·435	92·5	42·0	82·3	46·8	64·5	67·5	41·7	54·7	10	2·64	W.N.&E.	5	6
April ...	·784	·507	·673	·751	·452	·590	56·4	·576	54·4	·426	102·9	44·8	90·1	50·0	70·2	71·0	43·4	57·6	6	1·92	N.W.&E.	3	5
May ...	·671	·368	·554	·578	·326	·468	62·5	·524	60·7	426	113·6	55·8	104·0	59·0	79·1	75·2	44·3	62·3	8	2·73	E. & N.	2	3
June ...	·610	·257	·447	·542	·202	·364	70·5	·593	69·0	·478	116·0	63·6	102·0	67·1	84·3	81·2	55·0	69·5	8	4·40	N.E.&W.	2	3
July ...	·540	·308	·386	·459	·249	·328	74·3	·730	75·6	·641	111·5	66·0	95·7	68·3	83·0	82·0	62·1	73·9	11	6·94	N. & W.	5	5
August ...	·649	·256	·441	·525	·213	·367	73·3	·717	74·7	·635	112·4	66·7	95·1	68·2	82·5	82·0	62·8	73·5	9	9·07	S. & W.	4	4
September ...	·677	·409	·572	·573	·329	·480	68·4	·633	69·3	·537	109·3	60·7	92·0	64·0	80·5	80·2	53·7	69·7	3	1·39	N.N.&E.	2	3
October ...	·868	·634	·747	·770	·528	·655	58·6	·605	57·5	·486	104·8	50·4	91·1	55·1	72·7	74·3	44·9	59·1	5	·69	N.N.&E.	2	3

NOTE.—The height of the Barometer Cistern above mean sea level at Karáchi is 2,232·41 feet

Mean Velocity in miles of the winds which blew at Dehra during 12 months of 1876-77 for each hour of the day.

CIVIL HOURS.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.
0 to 1	2·70	3·27	2·89	2·20	1·78	2·68	2·33	2·50	2·50	2·65	2·03	2·73
1 „ 2	2·30	2·47	2·63	2·32	1·11	1·96	1·50	2·03	2·17	1·73	1·84	2·63
2 „ 3	2·19	2·77	2·56	2·04	0·96	1·75	2·20	1·87	1·50	1·58	1·13	2·47
3 „ 4	2·19	1·90	1·96	1·84	1·26	1·43	1·30	1·52	1·43	1·04	1·13	2·30
4 „ 5	1·70	1·97	1·85	1·68	0·89	1·07	1·13	1·07	1·47	1·15	1·26	1·77
5 „ 6	1·59	2·00	1·78	1·92	0·89	1·32	1·33	1·28	1·10	0·69	1·68	1·80
6 „ 7	1·70	1·80	2·07	1·88	0·67	1·29	0·97	0·76	1·57	1·12	1·19	1·57
7 „ 8	0·78	1·50	1·30	1·56	0·74	1·32	1·30	0·86	1·20	1·35	0·94	1·33
8 „ 9	1·56	1·40	0·93	1·72	0·85	1·50	1·43	1·69	1·90	2·04	1·42	1·37
9 „ 10	2·26	1·63	1·56	1·60	1·48	1·75	2·23	2·28	2·47	2·46	2·10	1·77
10 „ 11	2·96	2·37	1·61	2·12	1·96	2·32	2·80	2·62	2·83	2·38	2·00	2·10
11 „ 12	2·41	2·07	2·11	2·12	2·11	1·93	2·90	2·72	2·77	2·62	1·81	2·57
12 „ 13	2·81	3·10	2·37	2·58	2·29	2·21	4·10	3·13	3·76	2·27	1·90	2·43
13 „ 14	2·89	3·07	2·67	2·15	2·63	2·86	3·73	3·27	3·62	2·35	1·90	2·73
14 „ 15	2·78	3·07	2·33	2·08	2·48	3·07	4·47	3·60	4·10	2·42	2·29	2·57
15 „ 16	2·30	2·40	1·96	1·96	2·41	2·64	3·50	3·90	3·20	1·77	1·55	2·57
16 „ 17	1·37	0·77	1·00	1·24	2·37	3·14	3·33	3·37	2·97	1·46	1·26	1·41
17 „ 18	0·33	1·10	0·26	0·64	1·59	2·43	1·60	3·20	2·37	1·19	0·94	0·93
18 „ 19	1·48	2·43	0·89	0·72	0·89	1·36	0·73	2·20	1·30	0·51	0·77	2·00
19 „ 20	2·67	3·40	2·37	1·20	0·41	1·25	1·70	2·70	1·00	1·08	1·58	2·83
20 „ 21	2·89	3·60	2·96	2·16	1·04	1·57	1·47	2·67	1·43	1·31	2·19	3·23
21 „ 22	2·85	3·57	3·00	1·88	1·15	1·50	2·43	2·87	2·10	1·19	2·16	3·13
22 „ 23	2·93	3·30	2·96	2·32	1·19	1·64	2·33	3·30	2·17	1·69	2·29	3·63
23 „ 24	2·81	3·30	2·89	1·76	1·93	1·81	2·47	2·87	2·67	2·04	2·06	3·37
Sums ...	52·45	58·26	48·91	43·69	35·08	45·30	53·28	58·28	53·90	40·12	39·42	55·24
Average ...	2·19	2·43	2·04	1·82	1·46	1·89	2·22	2·43	2·25	1·67	1·64	2·30

Extract from the Narrative Report, dated 29th November 1877, of Major J. Herschell, R. E., on the prosecution of the reduction of Pendulum observations to Sea-level.

THE prosecution of the reduction of Captain Basevi's and Captain Heaviside's pendulum observations for varying attraction in different latitudes and at different heights has been alluded to in articles 88, 89 of the report for 1874-75 as occupying my attention. The enquiry was laid aside to enable me to attend to the business of the computing office during the following year, and I was unable to resume it until the beginning of 1877, when I was relieved of that charge.

It is not very easy to resume the thread of a subject of such intricacy. The interruption has not, however, been altogether without advantage. I have found it best to re-write the whole of what I had prepared in the first instance, in order to lead up more systematically from the comparative security of the earlier stages to the extreme uncertainty which characterizes, and, so far as I can foresee, must always characterize, the latter.

The investigations have been brought to a close, but the result can hardly be said to be satisfactory, the upshot being, in very few words, that the force of gravity (including in that term the attraction of the whole matter of the earth, wheresoever situated), as evidenced by the pendulum, remains not wholly explicable by any *known* conditions of the earth's form or constitution. Neither do the observed anomalies point with any certainty to an inference having a high degree of likelihood.

It is true that any one anomalous result may be readily explained by supposing a particular increase or decrease of density, of a particular volume of matter, in a particular direction, at a particular distance, and depth. *A fortiori*, several such influences being supposed will supply

all needful disturbing actions. The range of hypothesis thus extended is scarcely limited by the condition that many anomalous results have to be simultaneously so explained. Practically, indeed, it may be said to be not limited at all; for not only are the data whose unexplained deviations are sensibly larger than may be attributed to errors of observation, few in number, but nearly all of those are *most easily* explained by approximate and independent disturbing force. There is not, in my opinion, any indication of a *common* explanation sufficiently plausible to warrant extensive investigation for the purpose of a more precise evaluation of the data, *e.g.*, for determining the effect of the known distribution of land and sea.

It would be a mistake to read this as an evasion of a great difficulty. The difficulty *is* great, but it has been faced. The theory of the subject has been sufficiently mastered to enable estimates of the possible effects to be made for the remote and precise calculations for the proximate distribution. These failed, as has been said, to explain the observations. There remained the still more difficult question of the effect to be assigned on the supposition that the sea-level, as we know it and refer to it, is very different from the level which the sea would have if it were not drawn away from its primitive rest by the masses of the existing continents. Were the attraction of these surface masses to cease, *or were it negatived by corresponding lightness in subjacent strata*, the sea would retire and its level would fall, perhaps two or three thousand feet.* Were the continents, thus apparently raised by the same amount, "cast into the sea," in such a manner as to equalize its depth over the whole earth, the level would be again altered. All these changes, invented to reinstate the earth, so to speak, in a condition of more perfect regularity of figure, would involve alterations of attractive effect: *vice versâ* the change from the hypothetical primitive condition to that which now exists has involved disturbances of the previous state of attraction, which, it is presumable, are present in the force of gravity as we find it.

This part of the subject can only be treated by mathematics of a higher order than inadequate familiarity enables us to safely employ. Partly on this account, and partly from the very obvious consideration that widespreading causes of this character have too gradually varying effects to account for the abrupt anomalies of a local group, it has not been thought advisable to pass from investigation to calculation. Lines have, however, been traced, which it is hoped may be of service should the enquiry have hereafter to advance.

There are three stations of the Indian group which are of exceptional importance, *viz.*, Dehra, Mussoorie, and Moré. The first two form a pair, about 10 miles apart and differing 4,600 feet in elevation, upon the skirts of the Himalayas; the third is in the middle of the Himalayan range, at an elevation of 15,400. But for these three, the Indian group would have taken its place among other pendulum stations, and would have lent itself sufficiently to the various explanations which have been framed to account for the anomalies which appear so generally in this class of work. These, on the contrary, defy those explanations. Accepting the vibration-number as practically the true measure of gravity at a spot, there is no way of accounting for the discrepancy of $3\frac{1}{2}$ vibrations per diem between the above named pair, after all known corrections have been applied, except by supposing a quite local variation of density, such as would suffice to cover the discrepancies at most of the other stations. If we must accept this as a fact, what need to reduce with extreme precision?

The case is quite analogous to what was long ago shown regarding latitudes, and only needs verification as regards azimuths.

The case of Moré differs in this, that there is no nearer comparison than with the numbers at the former pair. There would seem to be some 20 vibrations here unsusceptible of present explanation, if we accept that offered by the contested hypothesis of Sub-Himalayan tenuity.

I am not prepared to accept or reject that hypothesis, still less to discuss it here. It must be approached, if at all, from the geological side; and as the earth is held by some to be solid internally, and by others fluid, there are probably arguments against it as well as for it. It is, however, remarkable that the column of results obtained by separating the height-correction (by Young's rule) into its two proper components, and adopting the first only, *viz.*, that for mere elevation, is *more accordant* throughout than that which follows it, where the correction for subjacent mass is also applied. The hypothesis of Sub-Himalayan tenuity would forbid this last application, and derives, therefore, some support from the fact.

Nevertheless, I am constrained to say that it is impossible at present to adopt that or any other hypothesis, except as an inference; and that the broad conclusion to which I am led is this—pendulum results are subject to errors which we have no prospect of eliminating, and therefore their *accuracy of observation* should be regulated with regard to the *magnitude* of those errors, and their *frequency of locality* increased, both locally and widely:—locally, in order to extend our knowledge of the measure of this natural error or uncertainty; widely, in view of the fact that, at present, measures of gravity are the only kind of measure of a geodetic character which can be extended with any approach to generality over the whole globe.

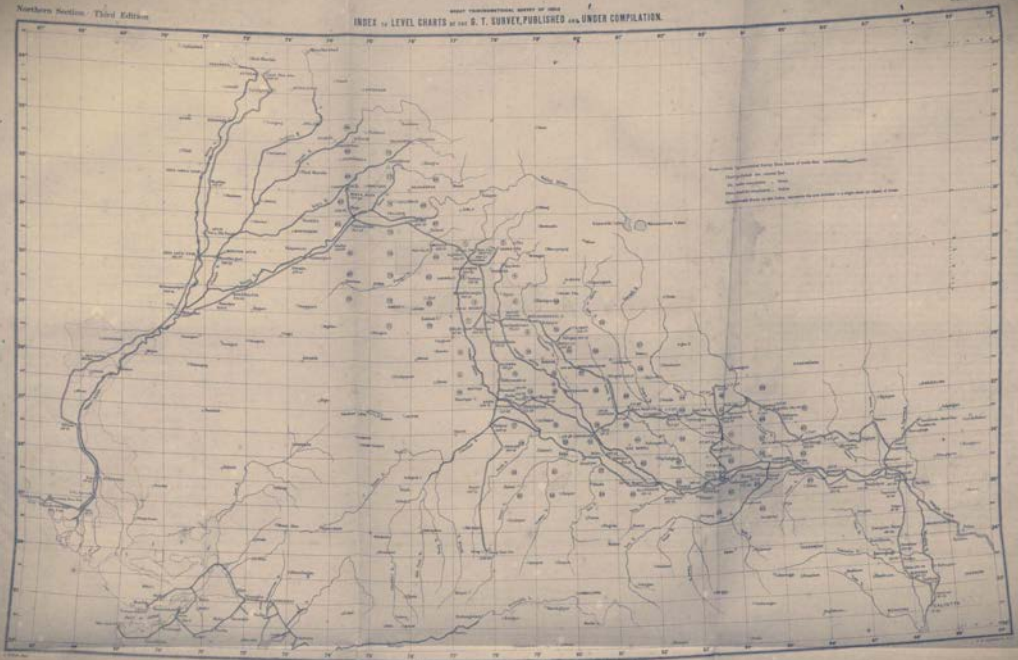
* The form of this sentence expresses intentionally the opinion which, in common with many geodetists, I feel bound to retain as the *safe* one, until the alternative italicised in the text has a good claim to supersede it. What follows necessarily ignores that alternative; but does not deny it.

Northern Section - Third Edition

GREAT TRIGONOMETRICAL SURVEY OF INDIA

INDEX to LEVEL CHARTS of the G. T. SURVEY, PUBLISHED and UNDER COMPILATION.

Sheet No. 1.



No. 189.

Extract from the Proceedings of the Government of India in the Department of Revenue, Agriculture and Commerce,—dated Simla, the 19th April 1878.

SURVEYS.

RESOLUTION.

READ—

Report on the operations of the Great Trigonometrical Survey during 1876-77, submitted by the Surveyor General of India with his letter No. $\frac{5}{1059}$ dated the 9th March 1878.

OBSERVATIONS.—The field work of the Department during the year falls into the following classes :—

1. Trigonometrical Surveys—
   (*a*) Primary.
   (*b*) Secondary.
2. Topographical Surveys.
3. Spirit-levelling operations.
4. Longitude observations.
5. Trans-frontier explorations.

Of these the last was unrepresented in the Report for 1875-76: the other four were carried on in continuation of the work of last year.

2. The Trigonometrical parties were employed in the South of the Madras Presidency, on the Eastern Frontier in Burma, and in Sind, in primary triangulation; and in Burma and the Assam valley in secondary triangulation. The following is a comparison of the outturn of work for 1876-77 with that for the previous year :—

PRINCIPAL TRIANGULATION.

Year.	No. of triangles.	Area covered in square miles.	Direct length in miles.	No. of stations fixed.
1875-76	48	4,182	217	38
1876-77	67	5,019	269	53

SECONDARY TRIANGULATION.

Year.	No. of triangles.	Area covered in square miles.	Direct length in miles.	No. of stations and points whose heights have been determined.
1875-76	363	9,413	439	633
1876-77	373	8,551	317	906

The figures for secondary triangulation above given include work done by the topographical parties in Kattywar, Guzerat, and Kumaun and Garhwál.

The outturn of the year is thus in excess of that of the previous year under every head of principal triangulation; under secondary triangulation the work done, though covering a smaller area, includes a larger number of triangles observed and stations fixed. In addition to the above, over 23,600 square miles of area (against 6,887 in the previous year) in the Himalayas and the mountainous portions of British Burma a number of points have been observed trigonometrically. These results are extremely satisfactory.

3. The topographical work was carried on in Kattywar, Guzerat, and Kumaun and Garhwál; in the first two of these it was in continuation of the work of last year, and was on the scale of 2 inches to the mile; the survey of Kumaun and Garhwál, which had been suspended in 1875-76 to admit of the

completion of the survey of the Dehra Dún, was resumed and finished. The following is a comparison of the outturn of the two years in Guzerat and Kattywar :—

	1875-76. Square miles.	1876-77.* Square miles.	
Guzerat ...	948 on 2 inch scale 923 on 4 „ „	1,988	on 2 inch scale.
Kattywar ..	2,253 on 2 „ „	1,716	

The outturn of work in Kattywar is thus somewhat less than in the previous year ; the decrease is due to the fact that Major Pullan had a smaller staff of assistants to work with than in 1875-76. By the Kumaun and Garhwál party an area of 870 square miles was triangulated for topography, and areas of 959 and 640 square miles were sketched topographically on the respective scales of half an inch and one inch to the mile. The country in which this party worked was of the most difficult character, the average height at which operations were carried on being about 16,000 feet above sea level, while the snow-line, owing to the severe winter, was much lower than usual, and the inhabitants of the upper valleys, on whom the surveyors depended for carriage and supplies, were detained in their winter quarters long beyond the ordinary time. The Governor General in Council congratulates the Department on the completion of this difficult and important field of work.

4. Spirit levelling operations were carried on in Guzerat by Mr. Rendell, and covered 358¼ square miles. In 1875-76 they had been superintended by Captain Baird as well, and under these two officers covered 420 square miles.

5. Colonel Walker gives an interesting analysis of the tidal observations taken in the Gulf of Cutch and at Tuticorin, upon the calculations of which Captain Baird was employed, in co-operation with Mr. Roberts of the Nautical Almanac Office, during the year in England. Arrangements were made in July last for a systematic record of these observations at selected points on the coast of India, and Captain Baird is now engaged in carrying out these arrangements under Colonel Walker's direction.

6. Longitude observations were taken by Major Campbell and Captain Heaviside between Vizagapatam and Madras, Vizagapatam and Bellary, and Mangalore and Bombay, completing the series of observations in Southern India commenced in 1872-73. These officers after finishing this work proceeded to determine the differences of longitude between Bombay, Aden, and Suez, by which the connection between England and India was completed.

7. The section of the Report describing Himalayan explorations records the journey of one of the native explorers, known as the Mulla, through a portion of the course of the Upper Indus, which has long remained geographically unknown ; the whole course of this river has thus at last been mapped.

8. Satisfactory progress appears to have been made in the calculating and publishing departments of the Head-Quarters' office.

9. The Department lost at the close of the year Lieutenant Gibbs, Assistant Superintendent attached to the Guzerat Topographical party, a young officer of much promise. Since its close news has also been received of the death in England of Colonel Montgomerie, whose retirement in the course of the year 1875-76 was noticed in the review of that year's Report.

ORDER.—Ordered, that copy of this Resolution be forwarded to the Surveyor General of India .

(True extract.)

Offg. Secretary to the Government of India.

Govt. Central Branch Press, Simla.—No. 12 R, A. & C.—18-4-78—156

No.

1878

GOVERNMENT OF INDIA.

DEPARTMENT OF REVENUE, AGRICULTURE AND COMMERCE.

SURVEYS.

RESOLUTION.

No. 189, DATED SIMLA, THE 16TH APRIL 1878.

SUBJECT.

Review of the Great Trigonometrical Survey Report for the year 1876-77.

Govt Central Branch Press, Simla.—No 12 R., A. & C.—18-4-78—150

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